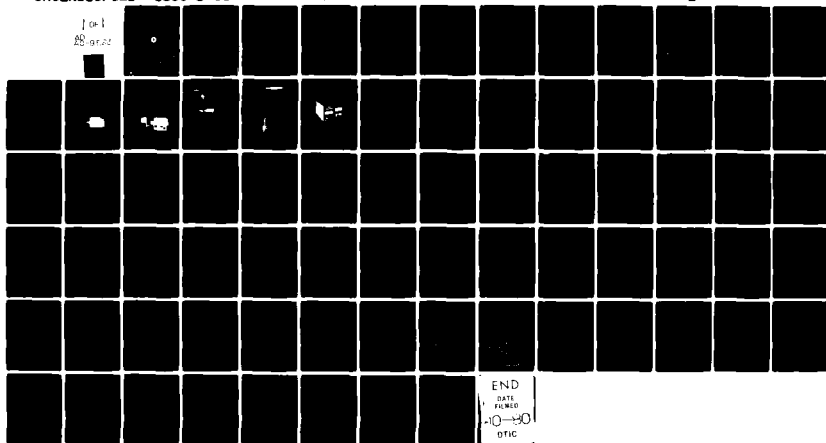


AD-A089 523 COAST GUARD WASHINGTON DC OFFICE OF RESEARCH AND DEV--ETC F/6 17/7
MAGNETIC SENSOR FEASIBILITY TEST FOR COAST GUARD VESSEL TRAFFIC--ETC(U)
AUG 80 T M DROWN
UNCLASSIFIED USCG-D-51-80 NL

1 of 1
28 pages



END
DATE
FILMED
10-80
DTIC

Report No. CG-D-51-80

LEVEL

12
B.S.

MAGNETIC SENSOR FEASIBILITY TEST FOR COAST GUARD VESSEL TRAFFIC SERVICES

AD A089523

LT T. M. DROWN



AUGUST 1980

Document is available to the U.S. public through the
National Technical Information Service,
Springfield, Virginia 22161

DTIC
ELECTE
SEP 25 1980

Prepared for

A

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard
Office of Research and Development
Washington, D.C. 20593

DDC FILE COPY

80 9 25 00

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The contents of this report do not necessarily reflect the official view or policy of the Coast Guard; and they do not constitute a standard, specification, or regulation.

This report, or portions thereof may not be used for advertising or sales promotion purposes. Citation of trade names and manufacturers does not constitute endorsement or approval of such products.

11) 4 - 1 - D - 51 - 8A

Technical Report Documentation Page

| | | | | | |
|---|--|--|---|--|--|
| 1. Report No. CG-D-51-80 ✓ | | 2. Government Accession No. AD-A089 533 | | 3. Recipient's Catalog No. | |
| 4. Title and Subtitle (16) Magnetic Sensor Feasibility Test for Coast Guard Vessel Traffic Services, | | | | 5. Report Date August 1980 | |
| | | | | 6. Performing Organization Code G-DST-3 | |
| 7. Author(s) (10) T. M. DROWN | | | | 8. Performing Organization Report No. (12) 766 | |
| 9. Performing Organization Name and Address Office of Research and Development U. S. Coast Guard ✓ Washington, D. C. 20593 | | | | 10. Work Unit No. (TRAIS) | |
| | | | | 11. Contract or Grant No. | |
| 12. Sponsoring Agency Name and Address Office of Marine Environment and Systems U. S. Coast Guard Washington, D. C. 20593 | | | | 13. Type of Report and Period Covered (9) Final Report, | |
| | | | | 14. Sponsoring Agency Code G-WWM-1 | |
| 15. Supplementary Notes | | | | | |
| 16. Abstract The Coast Guard Office of R & D has an on-going project to test the feasibility of using various sensors in the monitoring of vessel traffic in existing Vessel Traffic Service (VTS) operating areas. This report describes the effort involved in testing magnetic sensors. The report contains a description of both the sensor system configuration and the results of feasibility tests that were performed in Houston, Texas and Sault Ste Marie, MI. | | | | | |
| 17. Key Words Vessel Traffic Service Passive Sensor Systems Magnetometer VTS Operations | | | 18. Distribution Statement Available to the U. S. Public through the National Technical Information Service, Springfield, VA 22161 | | |
| 19. Security Classif. (of this report) Unclassified | | 20. Security Classif. (of this page) Unclassified | | 21. No. of Pages | |
| | | | | 22. Price | |

4-1-81 24

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

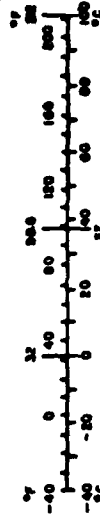
| Symbol | When You Know | Multiply by | To Find | Symbol |
|----------------------|----------------------|-------------|--------------------|--------|
| LENGTH | | | | |
| in | inches | 2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| y | yards | 0.9 | meters | m |
| m | miles | 1.6 | kilometers | km |
| AREA | | | | |
| sq in | square inches | 6.5 | square centimeters | sq cm |
| sq ft | square feet | 0.09 | square meters | sq m |
| sq yd | square yards | 0.8 | square meters | sq m |
| sq mi | square miles | 2.6 | square kilometers | sq km |
| ac | acres | 0.4 | hectares | ha |
| MASS (weight) | | | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 4.5 | kilograms | kg |
| sh | short tons (2000 lb) | 0.9 | metric tons | t |
| VOLUME | | | | |
| cu in | inches | 6 | milliliters | ml |
| cu ft | cubic feet | 16 | liters | l |
| cu yd | cubic yards | 36 | cubic meters | cu m |
| gal | gallons | 3.8 | liters | l |
| qt | quarts | 0.95 | liters | l |
| p | pints | 0.47 | liters | l |
| c | cups | 0.24 | liters | l |
| fl oz | fluid ounces | 0.03 | liters | l |
| teaspoon | teaspoons | 5 | milliliters | ml |
| tablespoon | tablespoons | 15 | milliliters | ml |
| cup | cups | 240 | milliliters | ml |
| quart | quarts | 950 | milliliters | ml |
| gallon | gallons | 3800 | milliliters | ml |
| barrel | barrels | 160 | liters | l |
| oil barrel | oil barrels | 160 | liters | l |
| dry barrel | dry barrels | 115 | liters | l |
| metric ton | metric tons | 1000 | kilograms | kg |
| short ton | short tons | 900 | kilograms | kg |
| long ton | long tons | 1000 | kilograms | kg |

TEMPERATURE (exact)

| Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature |
|------------------------|----------------------------|---------------------|
|------------------------|----------------------------|---------------------|

Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|----------------------------|-----------------------------------|------------------------|---------------|--------|
| LENGTH | | | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| km | kilometers | 0.6 | miles | mi |
| sq mm | square millimeters | 0.0015 | square inches | sq in |
| sq cm | square centimeters | 1.2 | square inches | sq in |
| sq m | square meters | 1.2 | square yards | sq yd |
| sq km | square kilometers | 0.4 | square miles | sq mi |
| ha | hectares (10,000 m ²) | 2.5 | acres | ac |
| MASS (weight) | | | | |
| g | grams | 0.005 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | metric tons (1000 kg) | 1.1 | short tons | sh |
| VOLUME | | | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | quarts | qt |
| cu m | cubic meters | 1.35 | cubic yards | cu yd |
| cu dm | cubic decimeters | 0.035 | cubic feet | cu ft |
| cu cm | cubic centimeters | 0.000035 | cubic feet | cu ft |
| cu mm | cubic millimeters | 0.000000035 | cubic feet | cu ft |
| TEMPERATURE (exact) | | | | |
| Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | | |



* 1 in = 2.54 inches (exactly). For other exact conversions and more detailed tables, use NIST Metric, Publ. 285, Guide to the SI, NIST Special Publication 800-47, 50 Conversions, Vol. C13.10.200.

TABLE OF CONTENTS

| | PAGE |
|--|------|
| 1.0 INTRODUCTION | |
| 1.1 BACKGROUND..... | 1 |
| 1.2 CONCEPT..... | 2 |
| 1.3 OBJECTIVE..... | 3 |
| 1.4 APPROACH..... | 3 |
| 2.0 SYSTEM DESCRIPTION | |
| 2.1 MAGNETIC SENSOR..... | 3 |
| 2.2 RADIO TRANSMITTER..... | 5 |
| 2.3 RECEIVER/PROCESSOR..... | 5 |
| 2.4 DISPLAY..... | 8 |
| 3.0 INSTALLATION | |
| 3.1 HOUSTON INSTALLATION..... | 8 |
| 3.2 ST. MARYS RIVER INSTALLATION..... | 12 |
| 4.0 OPERATIONS | |
| 4.1 INTRODUCTION..... | 14 |
| 4.2 DEMONSTRATION..... | 14 |
| 5.0 CONCLUSIONS | |
| 5.1 GENERAL..... | 15 |
| 5.2 MINIMUM REQUIREMENTS FOR FUTURE EFFORTS..... | 15 |

LIST OF FIGURES

| | | PAGE |
|-----------|--|------|
| FIGURE 1 | MAGNETIC VESSEL SENSOR OPERATION | 4 |
| FIGURE 2 | RF TRANSMISSION MESSAGE FORMAT | 5 |
| FIGURE 3 | DECODER BLOCK DIAGRAM | 6 |
| FIGURE 4 | CLIPPER FILTER CIRCUIT | 7 |
| FIGURE 5 | MAGNETIC DETECTOR HOUSING | 8 |
| FIGURE 6 | TRANSMITTER/ENCODER AND BATTERY PACK | 9 |
| FIGURE 7 | TRANSMITTER CONTAINER AND MAGNETIC DETECTOR HOUSING | 10 |
| FIGURE 8 | CONFORMAL PATCH ANTENNA | 11 |
| FIGURE 9 | SENSOR/TRANSMITTER DEPLOYMENT CONCEPT | 11 |
| FIGURE 10 | RECEIVER/PROCESSOR CABINET | 12 |

LIST OF APPENDIX

| | |
|------------|--|
| APPENDIX A | RECEIVED/DECODER OPERATION |
| APPENDIX B | REMOTE VESSEL MONITORING SYSTEM (RWMS) |

| | |
|--------------------|--|
| Accession For | |
| NTIS Grant | <input checked="checked" type="checkbox"/> |
| DDC 218 | <input type="checkbox"/> |
| Unprocessed | <input type="checkbox"/> |
| Justification | |
| By | |
| Distribution | |
| Availability Codes | |
| Dist | Avail and/or special |
| A | |

MAGNETIC SENSOR FEASIBILITY TEST
FOR COAST GUARD VESSEL TRAFFIC SERVICES

1.0 INTRODUCTION

1.1 BACKGROUND

In recognition of the increasing probability for the occurrence of a vessel accident in U. S. waters, and of the increasing potential for such an accident to cause injury to personnel and/or damage to vessels, port facilities and the environment, congress passed "The Ports and Waterways Safety Act of 1972", Public Law 92-340. Under this act, the Department of Transportation has the authority to:

- (a) "...Establish, operate and maintain Vessel Traffic Services and systems for ports, harbors and other waters subject to congested traffic
- (b) Require vessels which operate in an area of a vessel traffic service or system to comply with that service or system
- (c) Control vessel traffic in areas which (the Coast Guard) determines to be especially hazardous, or under conditions of reduced visibility, adverse weather, vessel congestion or other hazardous circumstances..."

The Coast Guard is the agency responsible for implementing the services mandated by this law.

In order for a Vessel Traffic Service (VTS) to operate efficiently, it must establish a surveillance system that provides updated information about ship traffic in its service area. Current VTS operations rely on two primary surveillance tools: radar and direct RF voice communications. Each tool has its practical limits. Radar can be used in a great many port areas, but it has a cost/benefit threshold that prevents it from being used in remote and/or restricted waterways. Direct voice communications are effective in determining the passage of vessels at predetermined checkpoints and to pass and obtain other pertinent information, but radio channels are already crowded in some ports. The Coast Guard Office of Research and Development has initiated a project to investigate surveillance systems that might be used to either augment radar and voice communications or efficiently replace them under certain circumstances.

Vessel Traffic Services (VTS) have been established in San Francisco CA, Puget Sound, WA, St. Marys River MI, Houston TX, New Orleans LA, and Valdez AK. Their normal method of operation is to provide an advisory to vessels operating in each service area. Information contained in the advisory includes vessel movement, hazards to navigation and weather. The information is collected and disseminated by one station in each VTS area called the Vessel Traffic Center (VTC). The majority of the information on vessel

movements is provided by the marine community on a cooperative basis.

The use of passive sensors in restricted waterways such as rivers, canals and some channels might provide additional surveillance capability. These restricted waterways present a unique circumstance whereby the flow of vessel traffic is well defined. The direction of flow is usually in two reciprocal directions, and there is limited room for deviation from the channel centerline. It appears that, by placing passive sensors at checkpoints along a restricted waterway, sufficient information can be developed to provide position information on vessels in transit. Careful site selection would insure that vessels always pass within a sensor's detection field.

As an initial attempt to demonstrate the feasibility of using passive sensors, currently available sensors in the acoustic and magnetic stimulus areas were considered. A cursory sampling of acoustic conditions in a candidate waterway revealed a complex array of acoustic signals from both distant and near-by sources. It was estimated that considerable effort would be necessary to develop a signal processor to accommodate the variety of acoustic signals and provide the necessary localized information. Such an effort was not considered appropriate for a feasibility demonstration. A similar sampling was performed using Vietnam War era magnetic sensing equipment. The results of this test indicated that magnetic sensing equipment was a promising candidate for the project.

1.2 CONCEPT

The primary means used by a VTS to monitor the progress of a vessel through the restricted waters of a service area is RF voice communications. Each VTS establishes checkpoints along its waterways and requires each participating vessel to report as it passes each checkpoint. Using the checkpoint information along with estimated speed of travel between checkpoints, the VTS personnel are able to maintain a dead reckoned position on all participating vessels. This surveillance scheme, called a Vessel Movement Reporting System (VMRS), is easily implemented and generally effective. There are, however, shortcomings. Sometimes vessels are late in making their checkpoint reports. Sometimes vessels cannot maintain the estimated speed of advance between checkpoints. These two factors serve to greatly reduce the accuracy of dead reckon positioning and, thereby, reduce the effectiveness of the VMRS. Two improvements that might increase the effectiveness of the VMRS are to: (1) increase the number of checkpoints to provide a more continuous flow of position information and (2) automate the reporting function both to make the reports more timely and to reduce human intervention.

Surveilling the VMRS checkpoint with some kind of sensor appears to have the potential to provide the following benefits: (1) vessel passages are automatically detected, thus eliminating the voice reporting requirement, (2) the output of a sensor system can be tailored to accommodate any data processing and display scheme ranging from a manual system to a fully automatic system and (3) in the proper configuration a sensor system would provide increased surveillance capability with decreased manpower requirements by allowing more checkpoints to be established. It appears that

passive sensors would provide and additional advantage because of their potential lower cost compared to active sensors, their smaller size, and because their operation does not necessarily require additional equipment to be carried by a cooperating vessel.

1.3 OBJECTIVE

The primary objective of this project was to demonstrate the concept of using passive sensors as a VTS surveillance system. Without developing a separate system for each known passive sensor, it was intended to demonstrate a system that would be typical of such configurations with regard to data acquisition, data transfer and display.

The secondary objective was to demonstrate the feasibility of using the magnetic sensor system to enhance existing VTS operations by using it in conjunction with a VMRS.

1.4 APPROACH

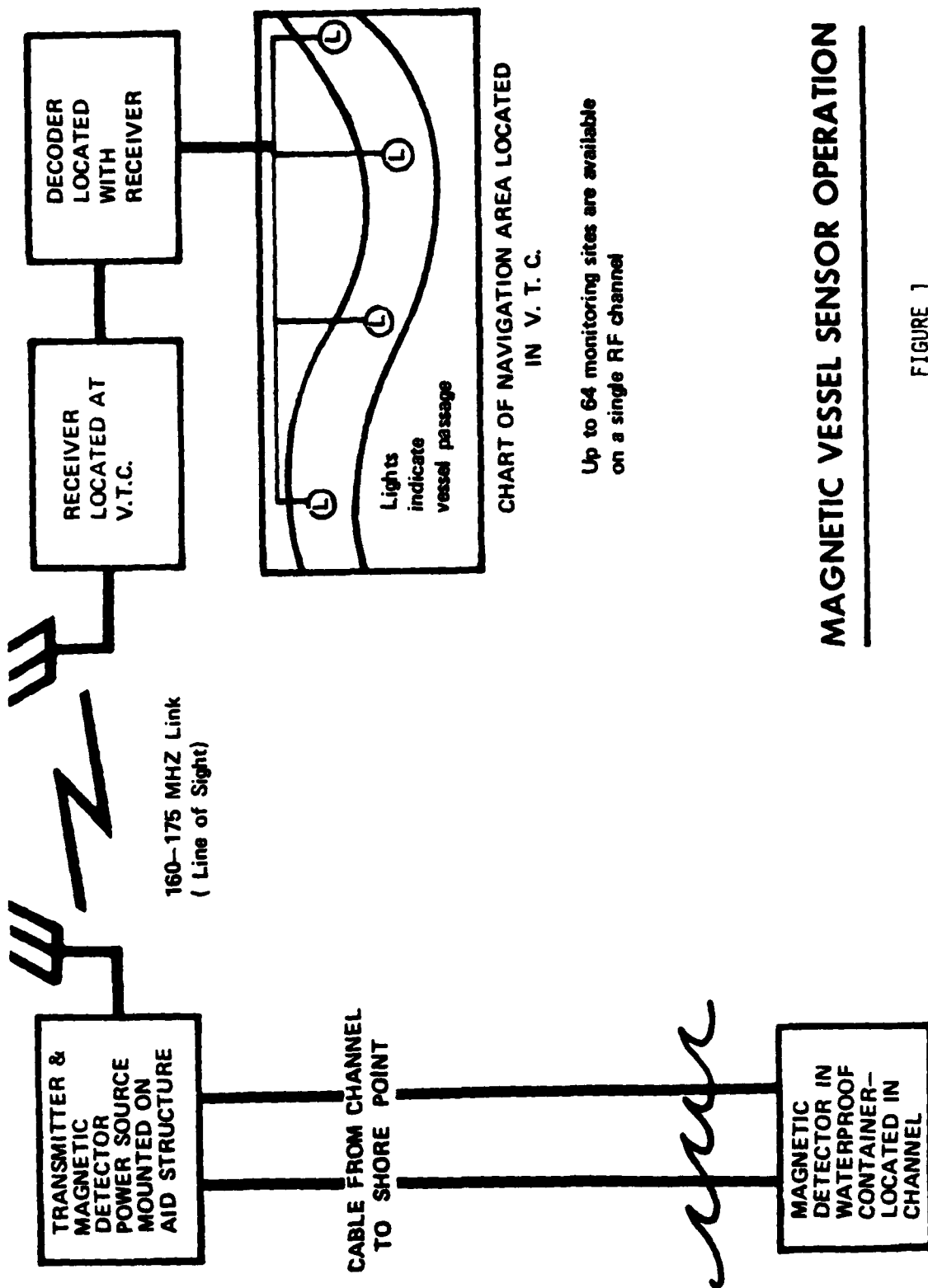
The demonstration system was based on equipment used in the Vietnam War. The Naval Surface Weapons Center (NSWC), White Oak: Silver Springs, MD was tasked with the adaptation and installation. The system was to be demonstrated in two waterways: (1) the Houston/Galveston Ship Channel, TX and (2) the St. Marys River, MI. The demonstrations were intended to provide the opportunity to judge the feasibility of using passive sensors, in general, and magnetic sensors, in particular, as a VTS surveillance tool. The first demonstration took place in Houston, TX. The second demonstration took place in Sault Ste. Marie, MI.

2.0 SYSTEM DESCRIPTION

The experimental system was called the Remote Vessel Monitoring System (RVMS). The RVMS makes use of existing battlefield equipment used in the Vietnam War. The system components are: (1) The magnetic sensor, (2) a VHF radio transmitter, (3) a receiver/processor and (4) a display. Whenever a vessel triggers the magnetic sensor, the sensor turns on the transmitter. The transmitter emits a short digital message which contains a unique identification number. The receiver/processor interprets the message and causes a printer to print out both the identification number of the transmitter and time of receipt of the message. An indicator light is lit on a display to indicate the location of the transmitter. Figure 1 shows the concept of operations.

2.1 MAGNETIC SENSOR

The U. S. Army nomenclature for the sensor used in the system is: Magnetic Detector, GSQ 180(V). It is designed to detect a disturbance of the earth's magnetic field caused by the passage of some mass (such masses usually contain iron or steel). The sensor uses a single axis, ring core, flux gate magnetometer developed by R. E. Brown of NSWC. In addition to the magnetometer, the sensor package includes transistorized detection and output circuitry which generates a pulse to trigger an RF transmitter. The



Up to 64 monitoring sites are available
on a single RIF channel

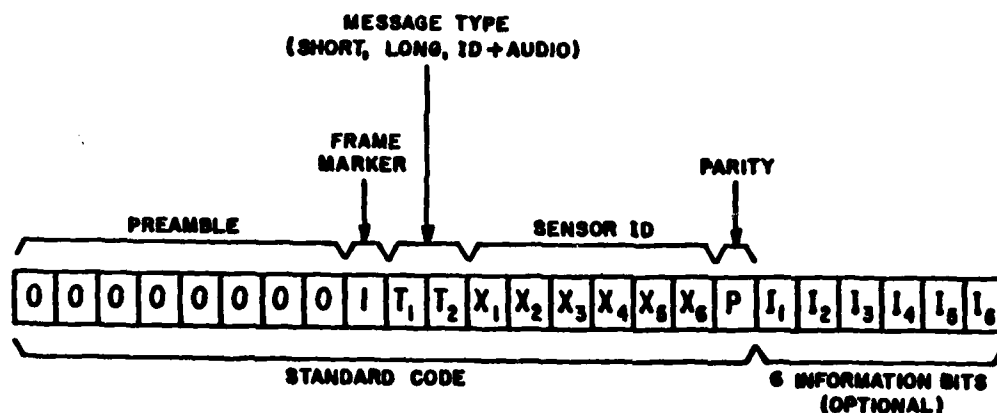
MAGNETIC VESSEL SENSOR OPERATION

FIGURE 1

detection circuitry prevents the output of transmitter trigger pulses faster than one every ten seconds. The sensor was designed to detect a person carrying a rifle when the person passed within a few feet of the sensor. However, since detection by the magnetometer depends on sensing a disruption in the ambient magnetic environment, detection is a function of the mass of the target passing the sensor and the speed with which it passes. The estimated detection range for ships moving at five to eight knots is 100 yards for a 200 ton ship, 200 yards for a 1,000 ton ship and 400 yards for a 10,000 ton ship.

2.2 RADIO TRANSMITTER

The radio transmitter is a Model T1233, GSQ 154 (V), Minisid transmitter. Used in conjunction with a encoder, KY 678 (GSQ), the transmitter sends an 18 BIT digital message which contains the transmitter's unique identification number. The message is transmitted using bi-phase modulation at 300 bits per second. The nominal output power is 4 watts. The transmitter is triggered by a 6 volt pulse of 5 msec duration which is output by the magnetic sensor package. Figure 2 shows the message format.

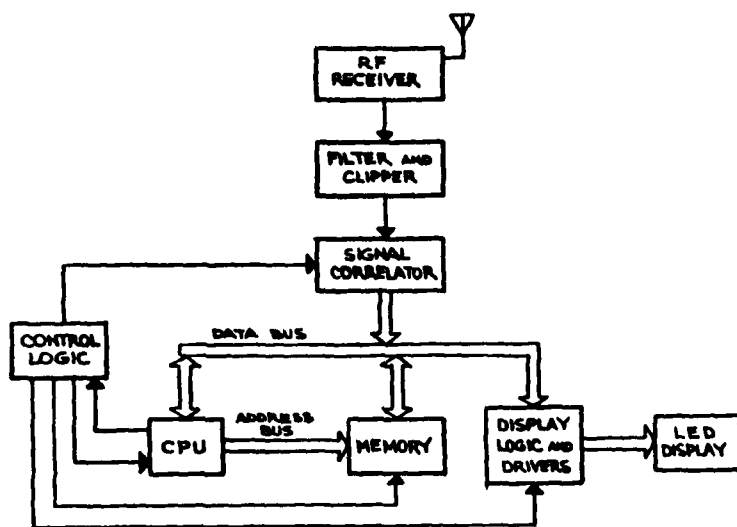


RF TRANSMISSION MESSAGE FORMAT

FIGURE 2

2.3 RECEIVER/PROCESSOR

The receiver/processor was patterned after the U. S. Army Radio Frequency Monitor, R167172/USQ 462. The frequency monitor was much more sophisticated than was required for the demonstration, and its price was high enough to justify building a receiver/processor for the demonstration system. Figure 3 shows the block diagram.



DECODER BLOCK DIAGRAM
FIGURE 3

The receiver is a commercially available VHF-FM, 6 channel, crystal controlled radio with an audio bandpass of 3kHz. The digital signal output to the processor is taken from the discriminator, filtered and hard clipped to form a digital data stream. The filter is AC coupled to the discriminator to prevent loading. Figure 4 is a schematic diagram of the clipper-filter circuit.

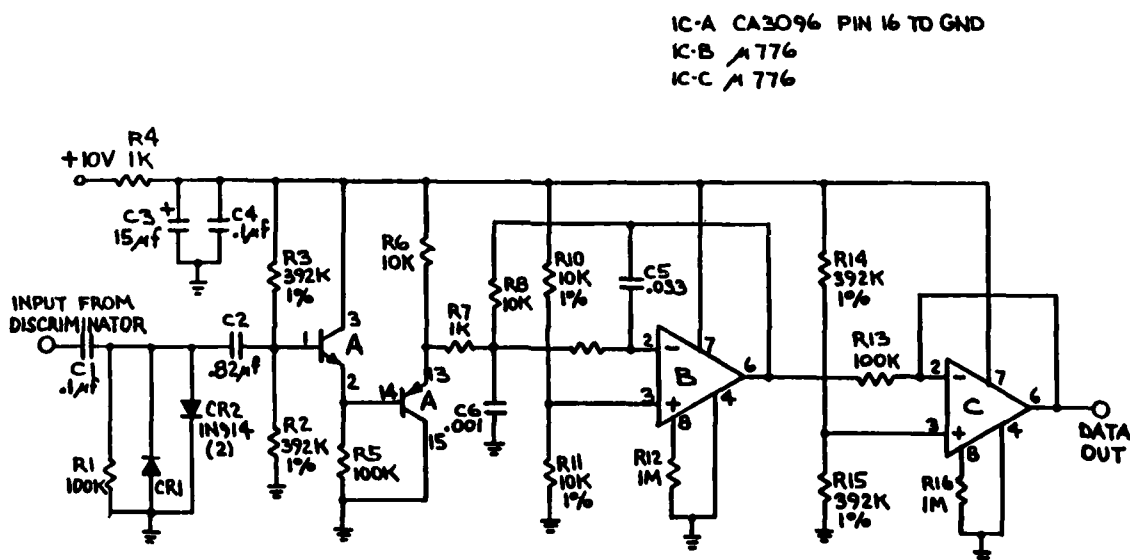
The processor is a software program implemented in an RCA CDP 1801 microprocessor. It performs radio frequency signal correlation, data decoding, message checking and information output for the display. Signal correlation is accomplished by sampling the digital data stream coming from the filter/clipper circuit in the discriminator at a rate that allows each bit to be sampled 8 times (sampling every 416 microseconds). The correlator uses any 8 successive samples to test for one information bit. If 8 successive samples contain the same binary value, the correlator passes an information bit of corresponding value through the data decode routine to the message checking routine.

The data decode routine stores each information bit in an 8 bit register. If 8 consecutive "ZERO" bits occur, the routine recognizes them as a message preamble and calls the message routine.

The message routine shifts all bits following the preamble through the 8 bit register and processes the contents of the register to determine: (1) if the message is of normal length or of an optionally longer length and (2) if there is correct parity. A valid message is indicated when the register is initially filled with 8 "ZERO" bits. Message information is obtained by shifting all the message bits through the 8 bit register into an additional

A display routine operates using the transmitter identification number contained in the digital message. The value of the identification number can range from 0 to 63. The binary representation of the number, which is contained in the digital message is shifted into an output register by the message routine. The display routine outputs the binary number to a printer interface and energizes a lamp drive circuit corresponding to the transmitter identification number. Appendix A contains a more detailed description of the receiver/processor operation.

The display consists of a 6 column printer and a number of LED indicator lights corresponding to each sensor location. A clock was interfaced to the printer so that a time annotation can be printed out along with the transmitter identification number.



3.0 INSTALLATION

This project involved two demonstrations, the first demonstration took place in Houston, TX in 1976. The second demonstration took place in Sault Ste. Marie, MI in 1978. Neither of the installations were exactly alike due to the on-site environment.

3.1 HOUSTON INSTALLATION

The Houston-Galveston ship channel is approximately 35 miles long. It averages 400 feet in width and has approximately a 40 foot depth. The sides and bottom of channel are mud. There is little, if no, current. The vessels that travel in the waterway range from pleasure craft to tugs with tows to large ocean-going ships. Because the sides and bottom are relatively soft, certain types of vessels can, and do, scrape the channel sides and bottom without fear of damage. In addition, the channel is constantly being dredged. The channel is lined with heavy industrial complexes along both sides. Appendix B contains a detailed description of the installation.

3.1.1 MAGNETIC SENSOR

The magnetic sensor packages were installed in a waterproof, aluminum (non-magnetic) housing, Figure 5. Although the sensors were unmodified, a



Figure 5 Magnetic Detector Housing

voltage regulator/output driver module was required to both reduce the supply voltage from the 36 VDC available to the 8.7 VDC required by the detector and to shape the sensor output pulse to match the RF transmitter trigger signal requirements. The sensors were deployed on the edge of the channel near aid to navigation towers. The weight of the aluminum housing caused the sensor to settle firmly into the mud, thereby preventing false alarms due to sensor movement. The orientation of the sensor in the housing caused the most sensitive axis of the magnetometer to be parallel to the plane of the channel and not directed toward the surface of the water where vessels would pass. This had no apparent effect due to the close detection ranges.

3.1.2 RADIO TRANSMITTER

The transmitter and encoder were housed in a cylindrical AN type metal shipping container measuring 10.5" in diameter by 42" high. The container also held a battery pack consisting of 25 Mallory mercuric oxide D size cells connected in series to provide 36 VDC, open circuit. Figure 6 shows the transmitter/encoder and the battery pack. The battery pack supplied power for both the transmitter and the magnetic sensor. A three conductor waterproof cable connected the sensor to the transmitter. The maximum tolerable cable resistance was 5,000 ohms. Figure 7 shows the transmitter container connected to the magnetic detector housing.

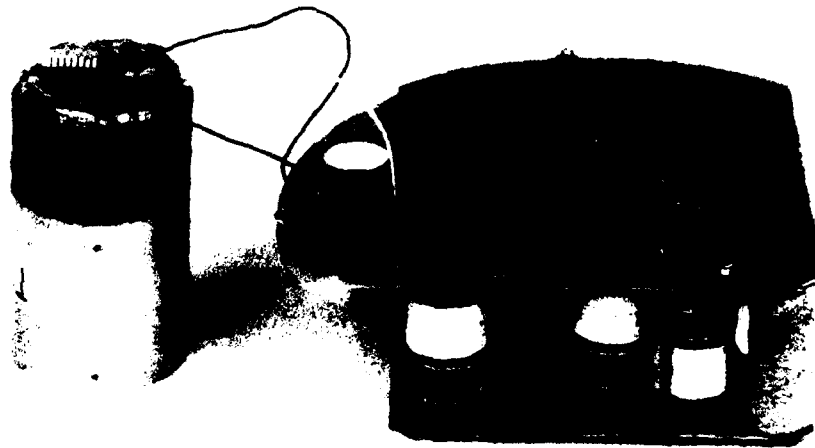


Figure 6 Transmitter/Encoder and Battery Pack

Figure 7
Transmitter and
Detector Hous-
ing

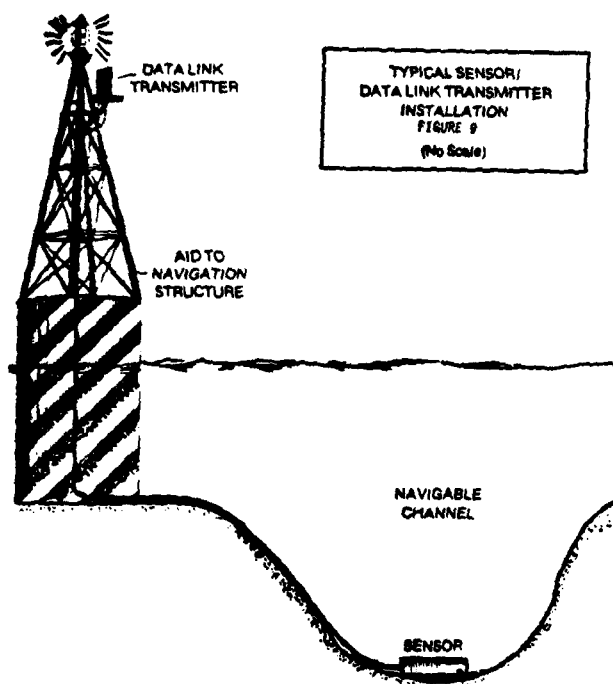


A conformal patch antenna was attached to the outside of the metal container, Figure 8. The antenna was a magnetic microstrip dipole produced on a piece of copper clad teflon-fiberglass substrate $1/32$ " thick. It measured 12.25" high by 8.0" wide and was horizontally polarized. Antenna impedance was 50 ohms. At the 168.0625 MHz operating frequency, the VSWR was 1.5:1.

The transmitter assembly was installed on an aid-to-navigation tower by attaching the container to the tower platform safety railing. The transmitter identification number was set to correspond to the aid-to-navigation number. Six transmitters and sensors were deployed. Figure 9 depicts the concept of the sensor/transmitter deployment.



Figure 8 Conformal Patch Antenna



3.1.3 RECEIVER/PROCESSOR

The receiver/processor was installed in the Vessel Traffic Center, located at the U. S. Coast Guard station in Galena Park, TX. The receiver/processor, the display printer and a digital clock were housed in a single metal cabinet, Figure 10. A corner reflecting receiving antenna with 10dB gain was installed on a 130 foot tower. The 16 nautical mile line of sight range provided by the tower was more than adequate to accommodate the RF transmission path to the farthest transmitter which was 6 nautical miles away.

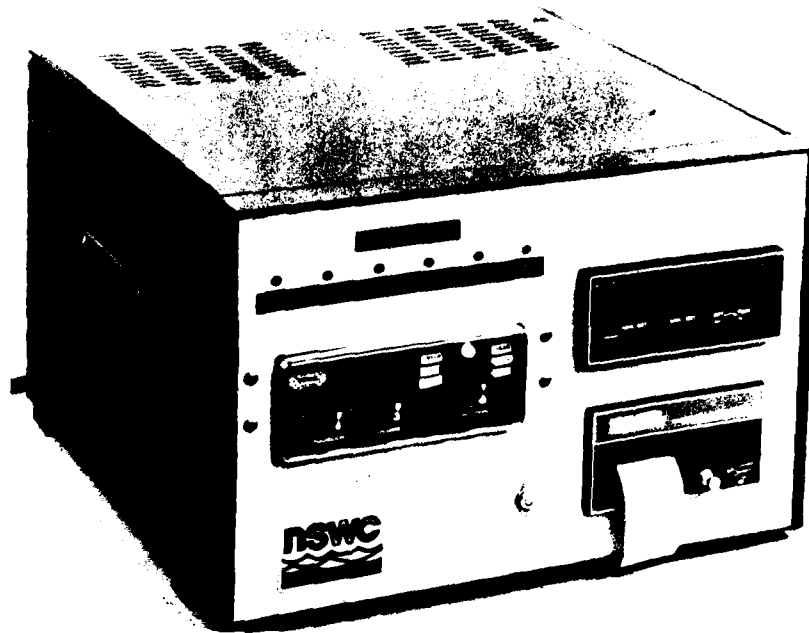


Figure 10 Receiver/Processor Cabinet

3.1.4 DISPLAY

The display consisted of the printer, installed as described above, and LED indicator lights located on the VTC plotting board.

3.2 ST. MARYS RIVER INSTALLATION

The St. Marys Rivers runs along the Canadian border of the upper peninsula of Lake Michigan. It is the single connection between Lake Huron and Lake Superior and carries a broad range of vessels from pleasure craft to ocean-going ships to iron ore carriers. The riverbed is rock and hard-pan.

The current ranges from 5 to 7 knots and is controlled from the St. Marys Falls to the river's mouth by a dam operated by the Army Corps of Engineers. The depth of the river is approximately 30 feet. Loaded ore carriers pass so close to the bottom that their propeller wash, at times, dislodges large rocks from the river bottom - some rocks are as large as a desk top.

3.2.1 MAGNETIC SENSOR

Initially, an attempt was made to deploy the magnetic sensors in the water, either in the channel or at the edge. To offset the effects of the current, the aluminum sensor housing was attached to an additional concrete weight. The total weight of the sensor package was too large for two men to handle, thus requiring the use of a boat with a lifting boom to deploy the sensors. The waterproof cable was also weighted. However, the cable was not weighted enough because the current moved the cable downstream, stressing it to a point where the cable connections at the sensor failed. Sensor deployment in the water was abandoned as being impractical for this particular demonstration.

An attempt was made to mount the existing detector housing out of the water. This was not successful.

Based on the premise that the best approach was to mount the sensor out of the water, a simple investigation of the operation of the sensing device was undertaken. This was accomplished by opening up a sensor package and observing the behavior of the detection circuit using an oscilloscope. A test set-up was established close to the river so that the reaction of the sensor to the stimulus of a passing ship could be observed. The test showed that the period of sensor stimulation lasted between 20 seconds and a minute, depending on the ship's speed. This indicated that a sensor bandpass of between 0.05 and 0.017 Hz was required for best operation. The bandpass of the magnetic sensor was 0.2 to 2.0 Hz. The sensor was modified to have a bandpass of 0.02 to 0.04 Hz. This modification improved the sensor operation.

Once the sensitivity of the sensor was improved, a high incidence of false alarms occurred from sensors placed in areas near roads and where other nonrelated activity was on-going. This problem was also solved by observing sensor operation during the false alarms. The remedy implemented was to build a missing pulse detection circuit to replace the circuitry that prevented sensor transmitter trigger output faster than once every ten seconds. The design theory was that a real target would cause a continuous string of output pulses over the period of time it was passing the sensor. The false alarm stimulus would be of short duration. Therefore, a circuit that required a consistent train of pulses for a given period of time could be made to discriminate against stimuli of shorter duration. This modification eliminated approximately 95% of the false alarms.

The modified sensor and the anti-false alarm circuit were mounted in the RF transmitter housing. Maximum range of the sensor was observed to be 600 feet for a large, ore carrying vessel traveling 3 to 5 knots.

3.2.2 RF TRANSMITTER

The RF transmitter was repackaged to be contained in a stainless steel box measuring 20"X16"X6". The transmitter, battery, sensor and anti-false alarm circuit were mounted on a flat metal plate that was attached to metal stand-offs inside the box. A conformal patch antenna was attached to the lid of the box. A lithium sulfur dioxide battery replaced the mercuric oxide battery pack. The transmitter operating frequency was 171.3625 MHz.

3.2.3 RECEIVER/PROCESSOR

The receiver processor was installed in the Vessel Traffic Center located at the U. S. Coast Guard Base in Sault Ste. Marie, MI. The receiver/processor, the printer and the digital clock were contained in an electrical cabinet that was mounted in the 19" rack of a standard console arrangement. A yagi antenna mounted on a 85 foot pole, served as the receiving antenna. Appendix C contains a description of the receiver/processor software.

3.2.4 DISPLAY

The display consisted of the printer installed as described above and a straight line representing of the St. Marys River drawn on the face of the cabinet. LED indicator lights mounted on the representation showed the position of activated sensors, on the map.

4.0 OPERATIONS

4.1 INTRODUCTION

The Vessel Traffic Services (VTS) at both Houston and Sault Ste. Marie operated in a similar manner. Each service maintained a position plot of participating vessels by dead reckoning using strategically designated checkpoints to obtain vessel position and verify the plot. VTS Houston maintains a plot that is continuously updated. VTS Sault Ste. Marie only updates their plot when ships report at the checkpoints. The plot at Houston is maintained on a representation of the ship channel; cards, representing vessels, are advanced along a plotting board to simulate vessels proceeding in the channel. At Sault Ste. Marie, the plot is kept in a log which contains the time vessels reported passing the designated checkpoints. Both VTS service areas contain sections of waterway where two-way traffic is allowed and sections where only one-way traffic is allowed. For the most part, passing due to one participating vessel overtaking another does not occur.

4.2 DEMONSTRATION

The demonstrations attempted to integrate the sensor system into regular operations. This attempt was not very successful. In Houston, there was three major problems:

- (a) Passing vessels hit two of the six sensors and destroyed them.

(b) The false alarm rate was high enough to substantially reduce VTS watchstander confidence.

(c) The lack of positive identification of the vessel triggering the sensor eliminated any benefit to the VTS watchstander, especially in sections of waterway where two-way traffic existed.

In Sault Ste. Marie, the major problem was the lack of positive identification of the vessel triggering the sensor.

5.0 CONCLUSIONS

5.1 GENERAL

The unanimous conclusion among the VTS personnel who used the system was that, as implemented, it provided little or no benefit to VTS operations. Two major shortcomings were readily apparent:

- (a) The lack of positive identification of vessels
- (b) The lack of operator confidence due to false alarms.

It was suggested that such a sensor system would have application as a perimeter monitor whereby the sensor would alert a watchstander to the presence of a vessel in some sector of a service area. The watchstander could then use some other surveillance technique to gather any required information.

With regard to passive sensors in general, this project points out the fact that they cannot be selected at random for use in VTS operations. Unlike radar, which is a sensor whose operating characteristics are fairly well understood, passive sensors have a wide variety of operating parameters. Passive sensors appear to require a specific design effort to meet the needs of each desired application. Information obtained about other sensors, which respond to acoustic, electrostatic, infra-red and seismic stimuli, indicates that any applications engineering effort begins with an analysis of the environment in which the sensor must function. Such an analysis includes identifying both the stimulus signature of the object to be detected and character of the ambient noise in the area of operation. The analysis must provide sensor sensitivity and bandwidth requirements and indicate any additional requirements for signal processing to allow for both the required level of object identification and noise discrimination.

5.2 MINIMUM REQUIREMENTS FOR FUTURE EFFORTS

The results of the demonstration project indicate that any future passive sensor development systems meet the following minimum requirements:

- (a) Provide a means of identifying the vessel that triggered the sensor. This is necessary both to resolve any ambiguities caused by vessels traveling in opposite directions and to identify vessels that are non-partici-

pants. It also provides additional discrimination against false alarms.

(b) Provide a means to discriminate against ambient noise. This is necessary to either eliminate false alarms or to reduce them to a level that is acceptable to a VTS watchstander.

(c) Allow for easy sensor deployment. It is apparent that deployment in a shipping channel will not work in every situation. Deployment by attachment to an aid to navigation structure or some other shore point appears to a much better approach. Deployment out of the water and either on or near shore has the dual benefit of easy initial installation and easy accessibility for maintenance.

APPENDIX A

RECEIVER/DECODER OPERATION

GENERAL OPERATION

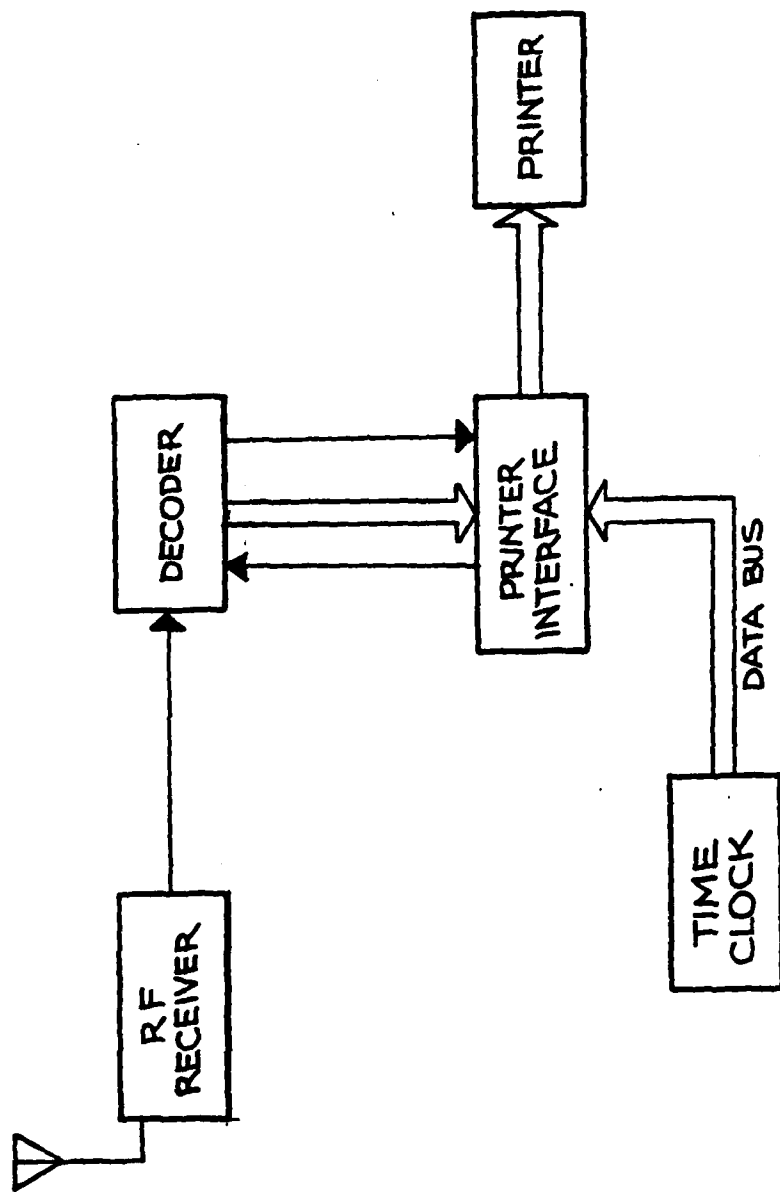
This system is comprised of three major sections: (1) a VHF-FM receiver, (2) decoder, and (3) time clock and printer. The block diagram of the system is shown in Figure 1.

The receiver, printer and time clock are commercially available pieces of equipment. The decoder consists of a signal clipper and correlator, a microprocessor, memory and control logic for the processor, and output display logic and LED drivers. A block diagram of the decoder is shown in Figure 2.

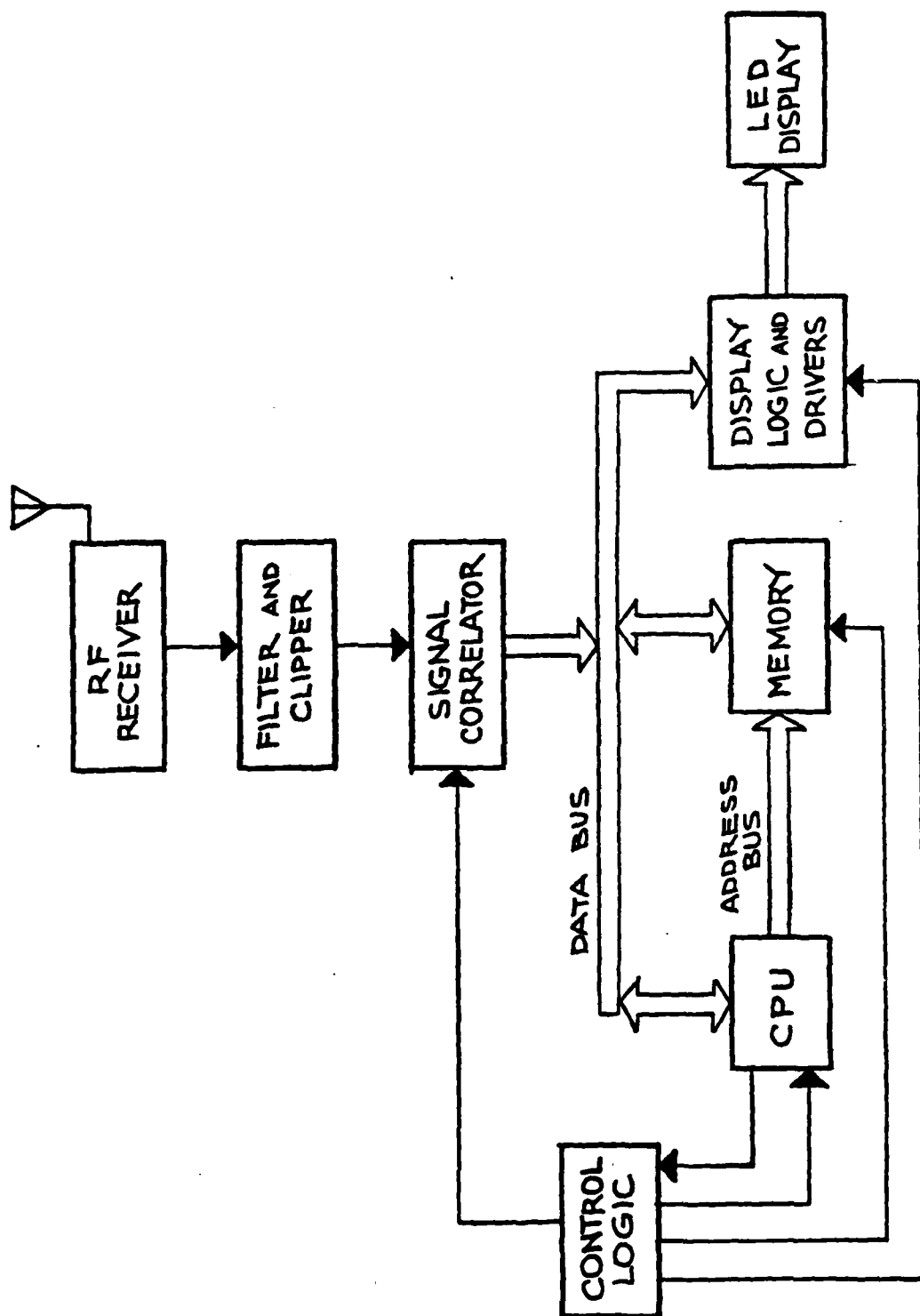
This unit was designed to be used in lieu of the USQ-46A Portatale Receiver in certain applications to detect and decode Phase III type RF messages. The Phase III RF link is a FSK 300 Hz biphase coded message. The Phase III RF transmission message format is shown in Figure 3. The decoder's software could be modified to decode any 300 Hz biphase coded message.

The receiver is a VHF-FM 6-channel crystal controlled radio. The discriminator output of the receiver is filtered and hard clipped into digital information to be sampled by the signal correlator.

The signal correlator compares the incoming digital data stream with a known digital data pattern (in this case a biphase zero) and calculates a value that indicates how much the incoming data represents the known data pattern. From this information, the microprocessor can determine if the signal is random noise or a valid transmitted message.



SYSTEM BLOCK DIAGRAM
FIGURE 1



DECODER BLOCK DIAGRAM
FIGURE 2

PHASE III R F TRANSMISSION MESSAGE FORMAT

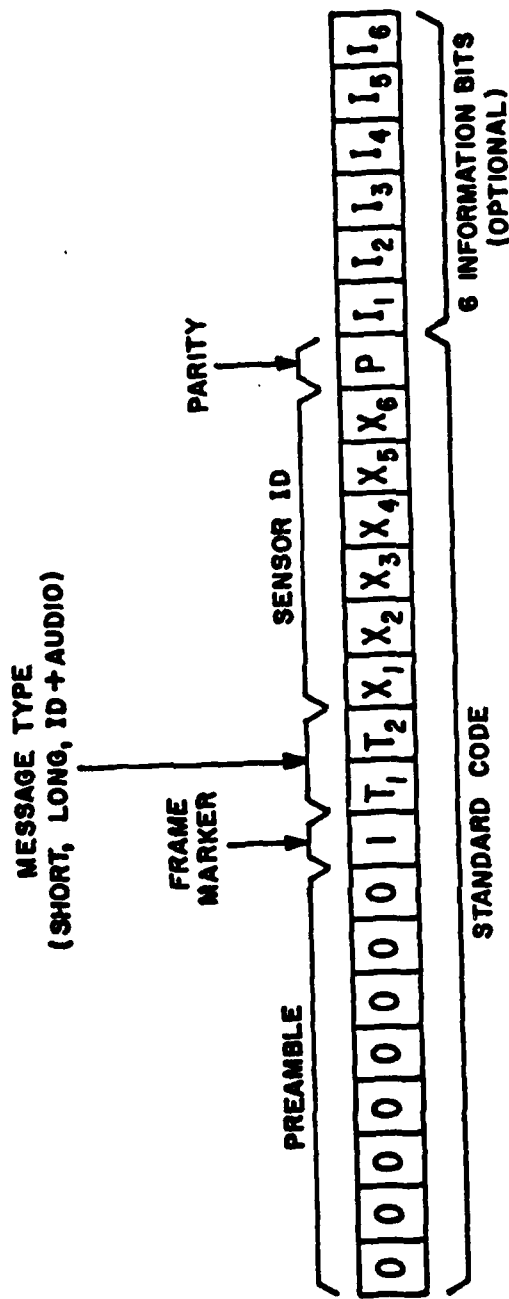


FIGURE 3

1

The central processing unit (CPU) is the RCA CDP 1801 microprocessor. The CPU performs the biphase data decoding, validity testing of received messages and information formatting for the LED display and printer.

When a transmitted message is received, the processor decodes the ID number associated with the message. The ID number and the time the message was received is printed and the corresponding display panel ID light is illuminated.

Decoder Circuit Description

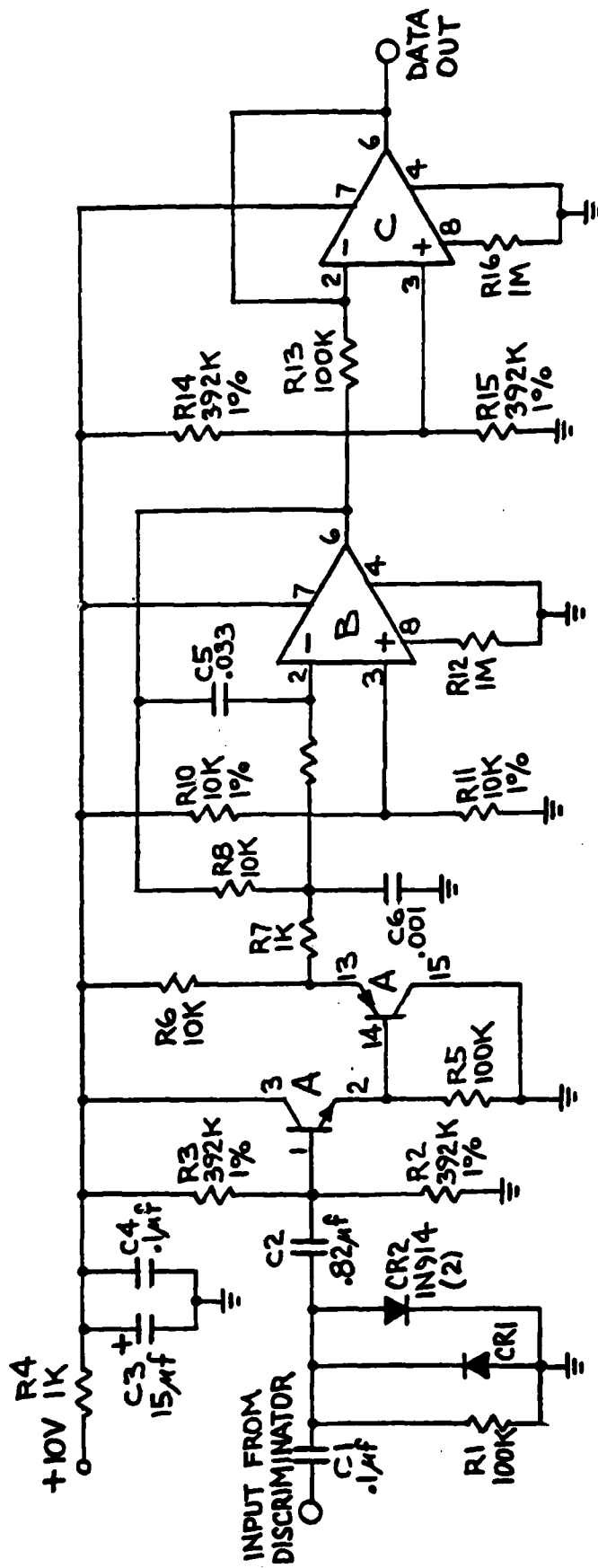
Filter-clipper. The discriminator output of the receiver is ac coupled to the filter to prevent loading. The signal, nominally one volt peak-to-peak, is passed through a 300 Hz, 2-pole, low pass filter with 20 dB of gain. Then the signal is hard clipped.

The schematic of the filter-clipper is shown in Figure 4. The first two transistors (IC-1) are used to buffer the signal from a ground reference to the +5 volt reference of the op-amps. The first op-amp (IC-2) amplifies and filters the signal and the second op-amp (IC-3) clips the filtered signal.

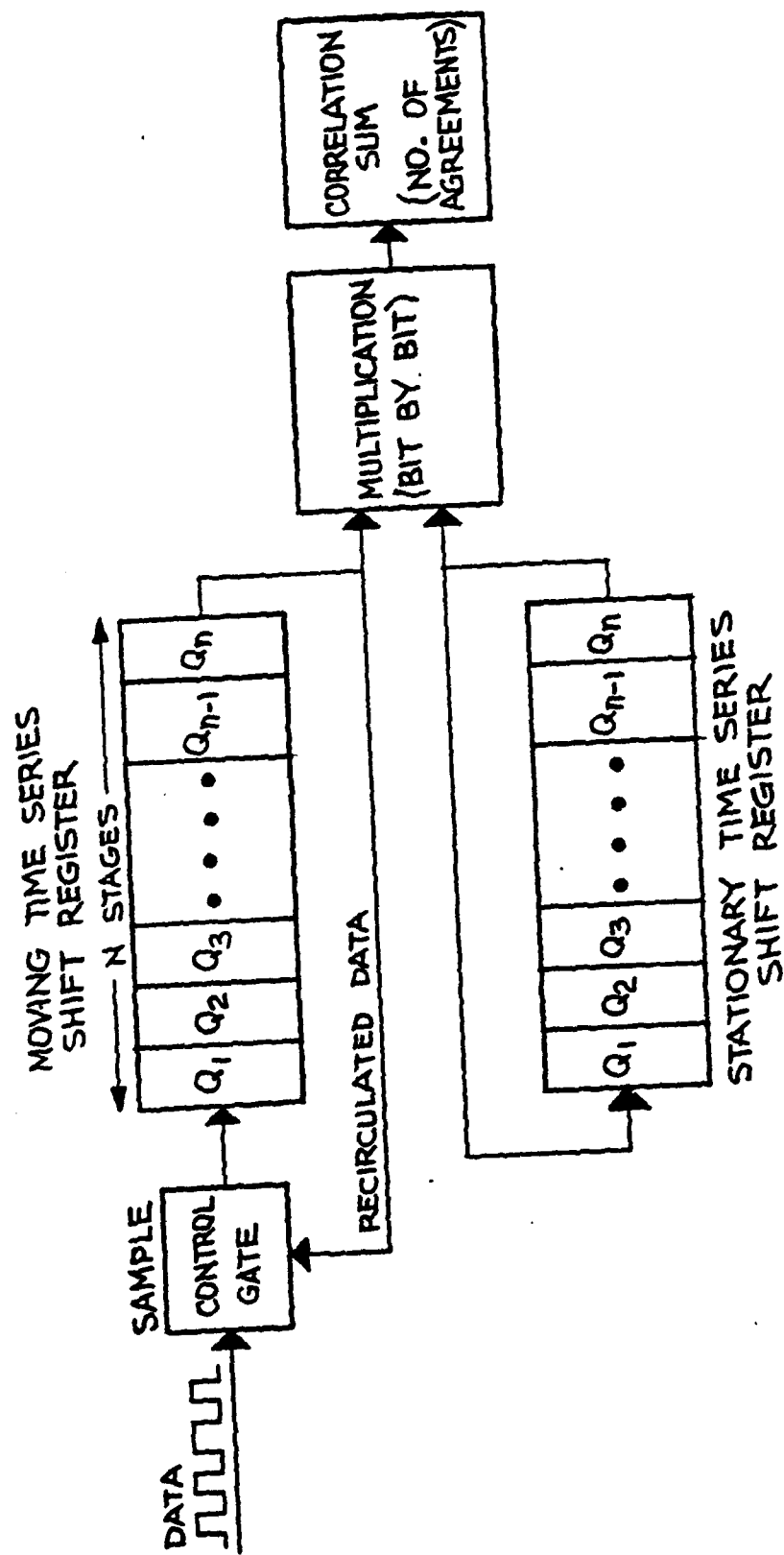
Signal Correlator. Signal correlation is a process in which two time functions are operated on to calculate a correlation sum. One method of doing this is a Delay Time Compressed (DELTIC) correlator. The DELTIC correlator stores a time compressed representation of the digital data in a serial memory, referred to as a Moving Time Series (MTS) shift register. The correlator compares the contents of this memory to the contents of the Stationary Time Series (STS) shift register, each sample period. Figure 5 shows a block diagram of the DELTIC correlator.

The contents of the MTS and STS shift register are recirculated during each sample period. By observing the outputs of the registers during this recirculation, a correlation sum can be calculated each sample period.

IC-A CA3096 PIN 16 TO GND
 IC-B μ 776
 IC-C μ 776



CLIPPER-FILTER
 FIGURE 4



DELAY TIME COMPRESSION (DELTIC)
CORRELATOR
FIGURE 5

The length (N) of the serial memory is equal to the number of samples per data bit (level of quantization) necessary to extract the transmitted data from noise.

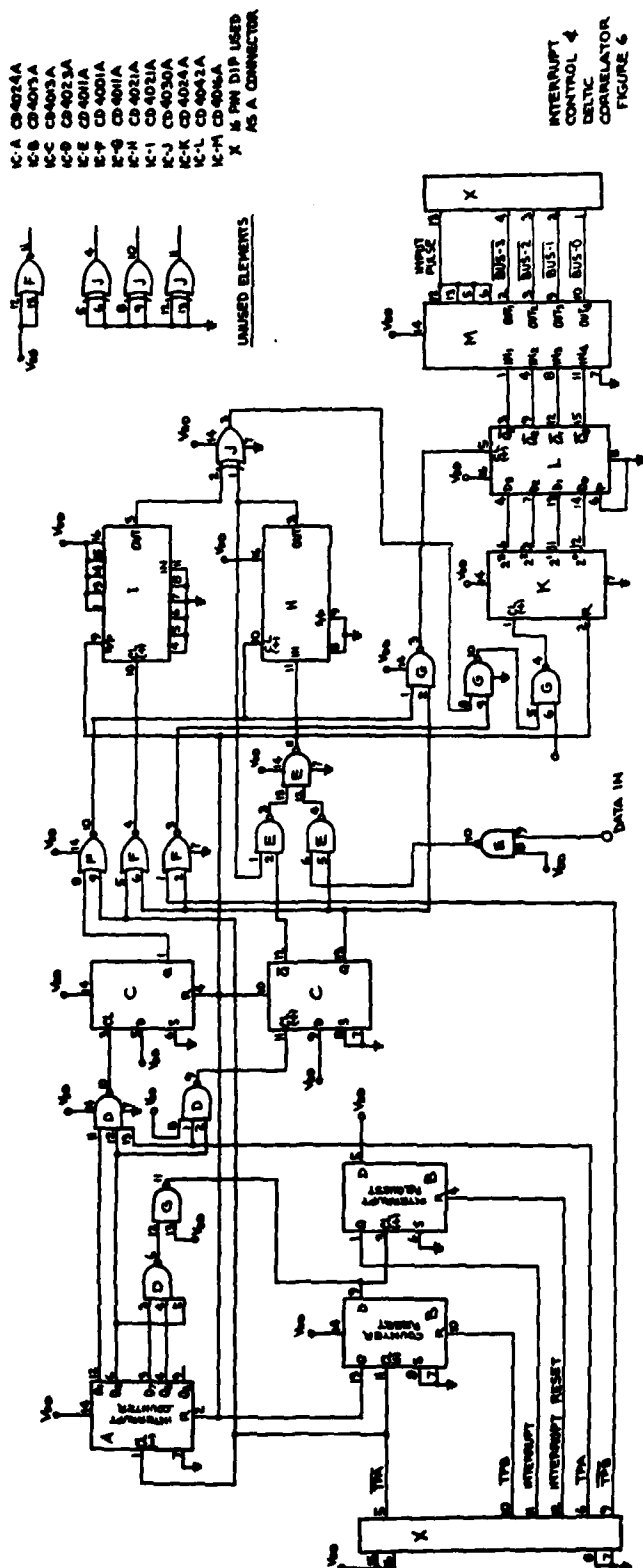
The sampling rate of the correlator is a function of the frequency of the data to be correlated and a function of the level of quantization (Q) that is required. The maximum frequency of the Phase III message being decoded is 300 Hz.

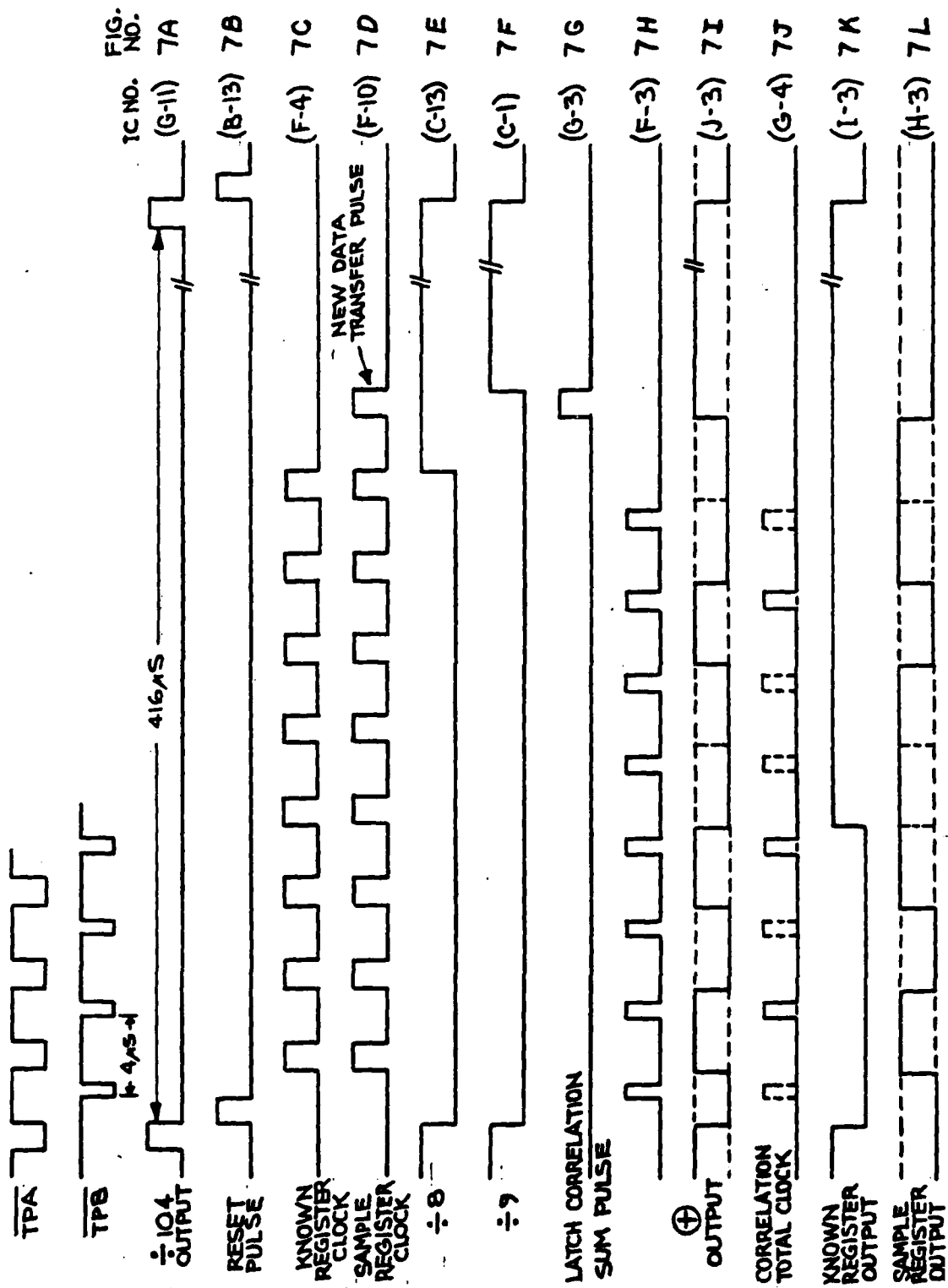
For this application, a quantization level of eight is sufficient to obtain enough information to decode an incoming message. The sampling rate (T_{SR}) = Q/signal period.

$T_{SR} = 8/(1/300 \text{ Hz})$ or 416 microseconds. The timing pulses of the microprocessor, TPA and TPB, are counted for this time base. At each sampling period (every 416 microseconds) a correlation sum is calculated and the processor is interrupted to process the new sum.

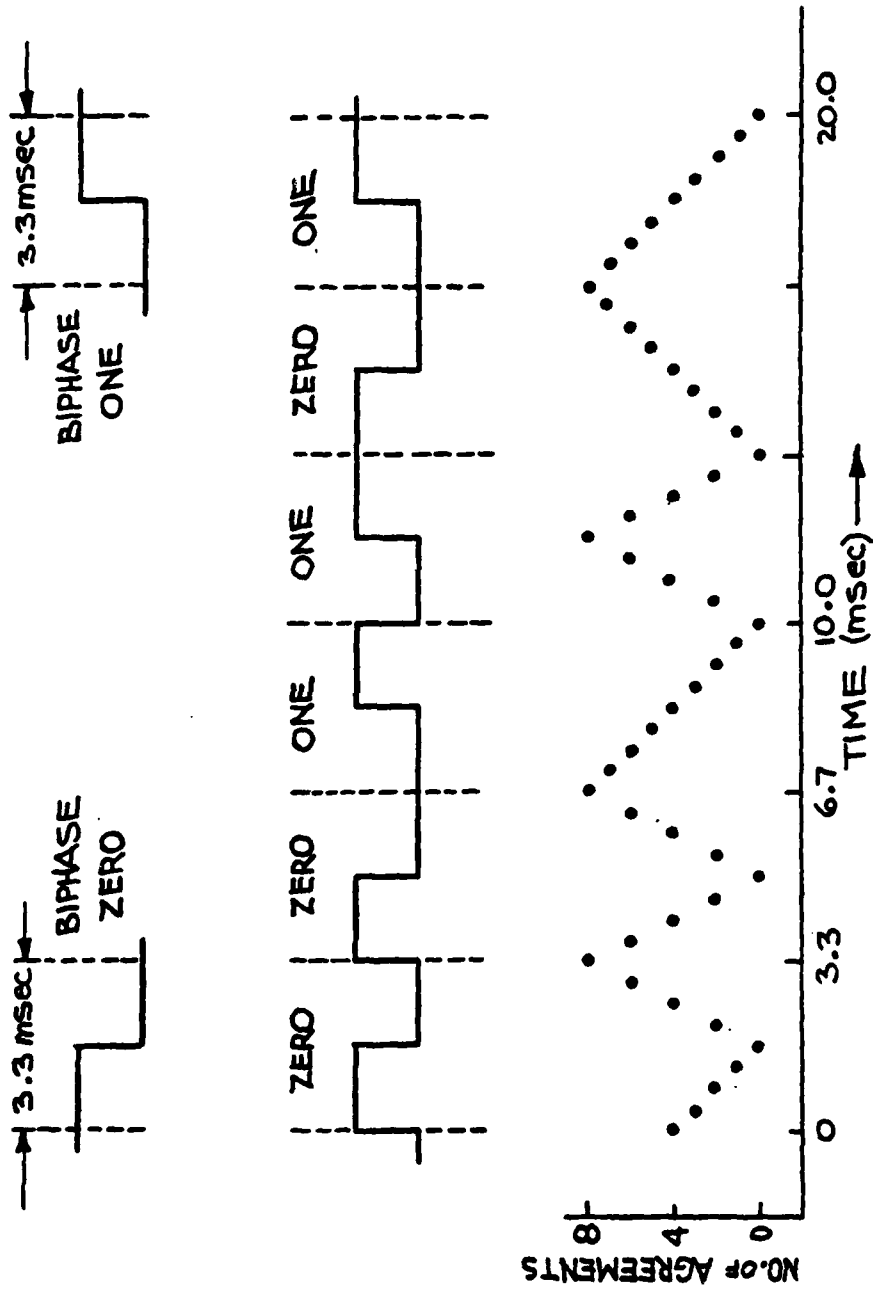
The schematic of the DELTIC correlator is shown in Figure 6. At the beginning of every sample period all counters are set to zero by the reset pulse, Figure 7. The first eight clock pulses of the known and sample shift register clocks (Fig 7) after the reset are used to shift the two data registers of the correlator. The ninth pulse of the sample register clock is used to transfer a new data sample into the sample data register (IC-H).

The data in the MTS shift register is circulated from the output to the input so that after eight clock pulses the register contains the same information it did at the start of the cycle. The ninth pulse stores a new sample bit in the first register location, shifting the other bits down one position, and causing the oldest sample bit to be lost. Therefore, every eight samples (3.3 msec) there is a completely new time compressed replica of the signal in the MTS shift register.

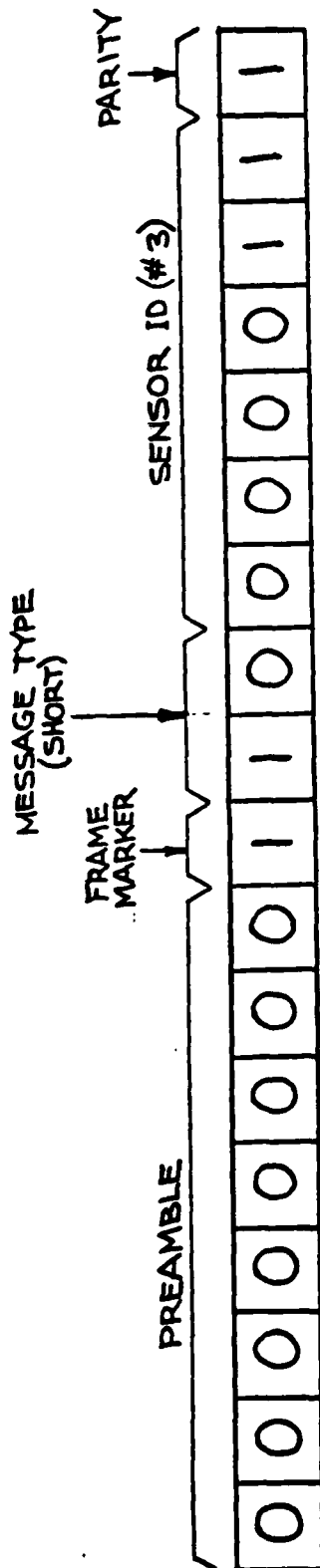




DELTIC CORRELATOR TIMING DIAGRAM
FIGURE 7



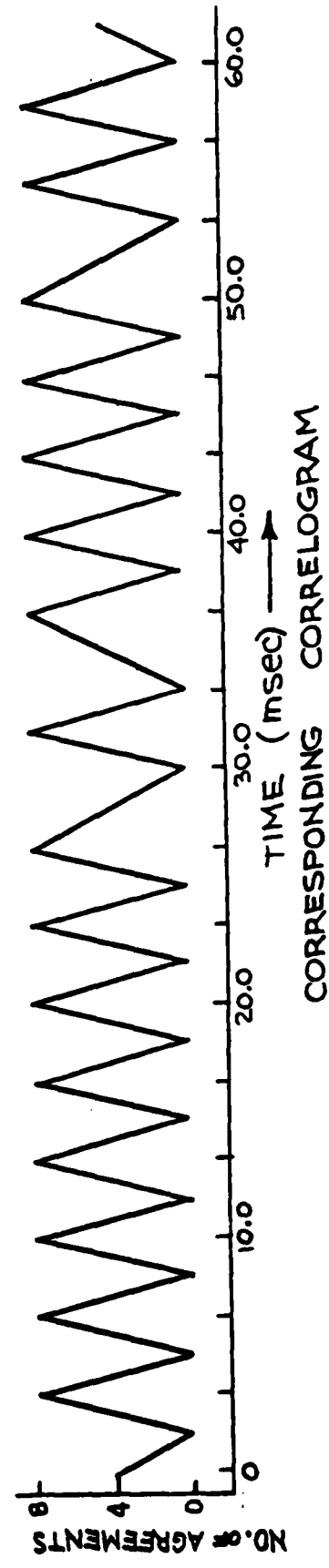
BIPHASE INFORMATION AND CORRELOGRAM
FIGURE 8A



MESSAGE FORMAT



BIPHASE INFORMATION



SAMPLE MESSAGE
FIGURE 8B

At the start of the sample cycle, the biphase zero pattern is jammed into the STS shift register (IC-1) to be compared bit by bit to the MTS shift register.

The MTS shift register and STS shift register are multiplied and summed to calculate a correlation total for the sample period. In Figure 7 this is demonstrated by performing the exclusive or function on the known and sample register outputs. The correlation counter (IC-K) counts the number of correlation total clock pulses (Fig 7) and this sum is stored in a set of latches (IC-L) by the latch correlation sum pulse. The microprocessor can interrogate this sum when it is ready. A sum of zero is 100% correlation and eight would be 0% correlation. (0% correlation is interpreted as a binary zero and 100% correlation is a binary one.)

Figures 8A and 8B show examples of the biphase message format with the corresponding correlograms. This format is what is decoded into binary ones and zeros by the processor with the aid of the DELTIC correlator. Since a biphase one is of opposite polarity of a biphase zero, only one pattern must be recognized to distinguish both the one and the zero.

CPU Hardware. A microprocessor is used as the controller for the output display, output printer, and decoding the correlated biphase message information. The hardware needed to control the microprocessor is discussed in this section.

The processor hardware can be sectioned into three parts: (1) CPU, (2) memory, and (3) control logic.

The CPU is the RCA CDP 1801 CMOS microprocessor (COSMAC). Detailed explanation of this microprocessor can be obtained by reading RCA's literature on the 1801.

The memory is the HC-55, a hybrid package fabricated at the White Oak Laboratory. The HC-55 is a 512x8 bit array with the RCA CD4061AH static random-access memory (RAM) chips the basic building block. The memory board schematic is shown in Figure 9.

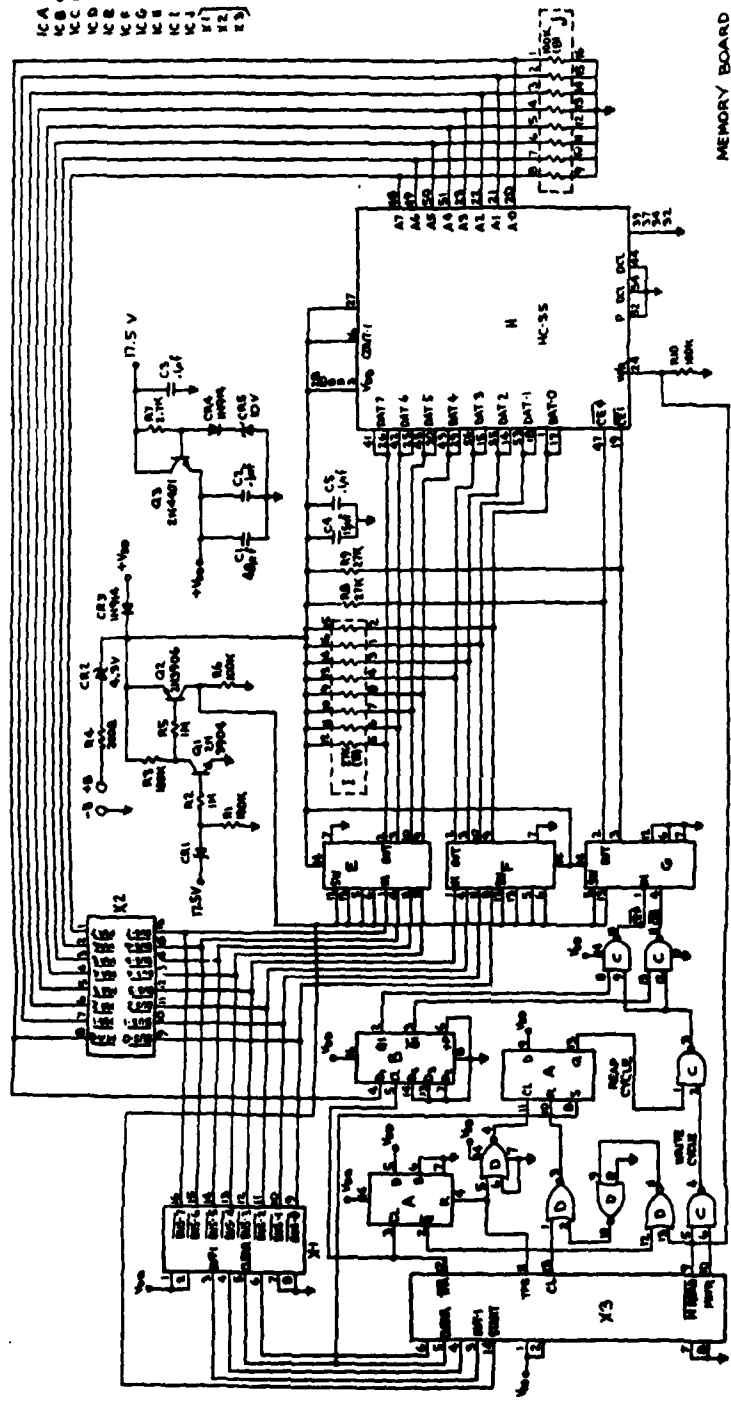
The memory is a non-volatile RAM by using a keep-alive battery. In this respect, the RAM functions both as the ROM and RAM for the system. To keep the memory alive, it is isolated from the rest of the system with switches (IC-E,F,G) in the bus lines and memory enable lines when power is lost. These isolation switches are controlled by a voltage level sensing switch (transistors Q1, Q2 and Zener CR1). This level sensing switch is to ensure that the memory will not be enabled during turn on and turn off transients.

The memory timing restrictions require some interfacing logic between the HC-55 memory and the COSMAC processor. The upper byte of the memory address is multiplexed on the address buss by COSMAC and latched by the \overline{TPA} pulse (IC-B). Only \overline{MAO} is latched in this case. The memory is enabled one clock cycle after \overline{TPA} for a read cycle and enabled during the MWR (COSMAC created) pulse for a write cycle. The rising edge of \overline{TPB} is used to disable the memory after each read cycle. $\overline{CE0}$ enables the lower half of the memory (bytes 0-255) and $\overline{CE1}$ enables the upper half of memory (bytes 256-511). The memory timing diagrams are shown in Figure 10.

Control logic consists of start up, interrupt, and input-output control for the processor. The circuit diagram of the CPU board is shown in Figure 11. Figure 12 shows the timing diagrams of the CPU control.

At power turn on, a clear pulse is generated to clear the CPU (IC-A,B) and initialize the output data register IC-A of Figure 13. At the end of the clear pulse, an interrupt inhibit

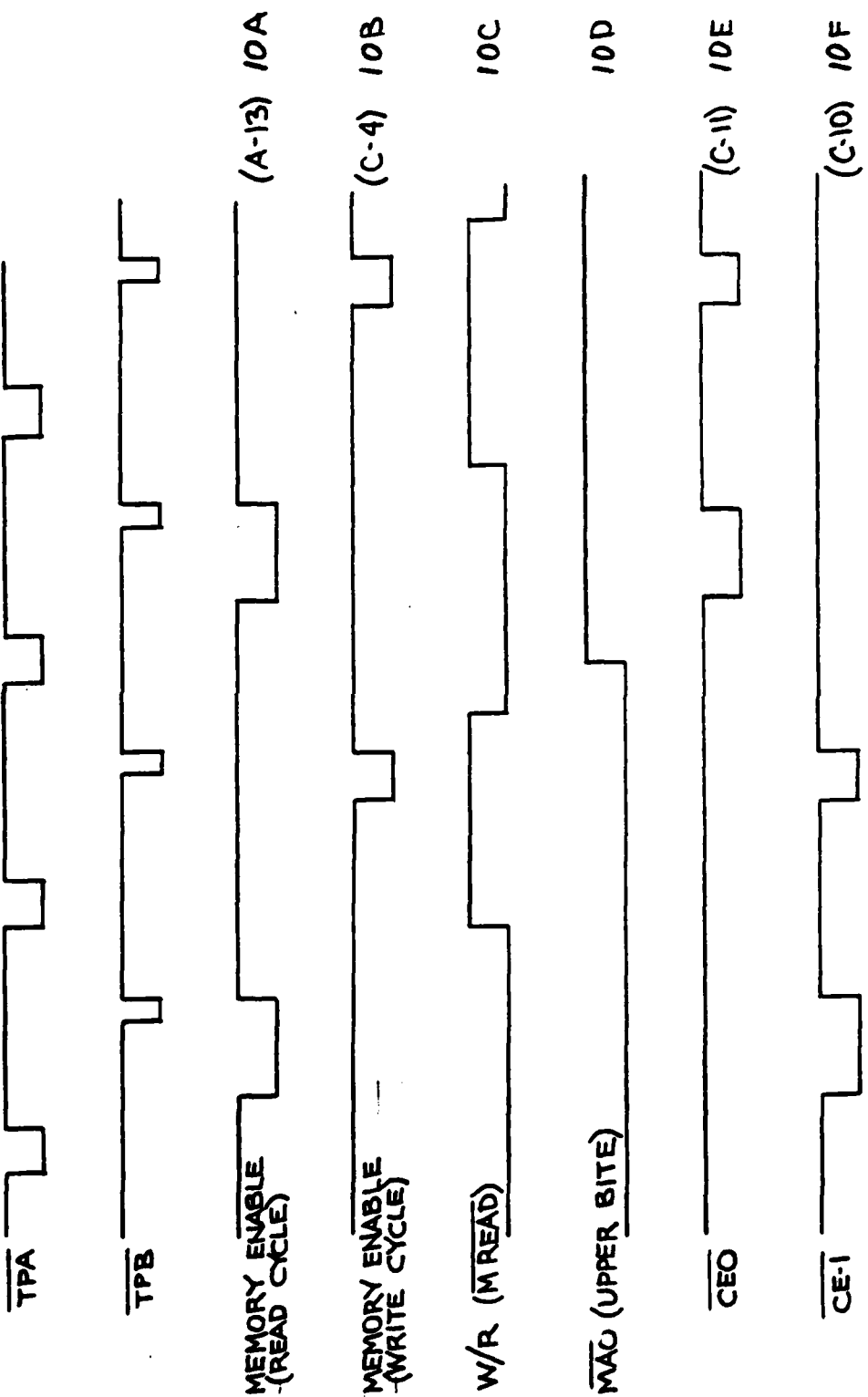
- IC A CD 4013
- IC B CD 4042
- IC C CD 4011
- IC D CD 4001
- IC E CD 4014
- IC F CD 4014
- IC G 54 PMT HYPERNO
- IC H 54 PMT HYPERNO
- IC I 54 PMT HYPERNO
- IC J 54 PMT HYPERNO
- IC K 54 PMT HYPERNO
- IC L 54 PMT HYPERNO
- IC M 54 PMT HYPERNO
- IC N 54 PMT HYPERNO
- IC O 54 PMT HYPERNO
- IC P 54 PMT HYPERNO
- IC Q 54 PMT HYPERNO
- IC R 54 PMT HYPERNO
- IC S 54 PMT HYPERNO
- IC T 54 PMT HYPERNO
- IC U 54 PMT HYPERNO
- IC V 54 PMT HYPERNO
- IC W 54 PMT HYPERNO
- IC X 54 PMT HYPERNO
- IC Y 54 PMT HYPERNO
- IC Z 54 PMT HYPERNO



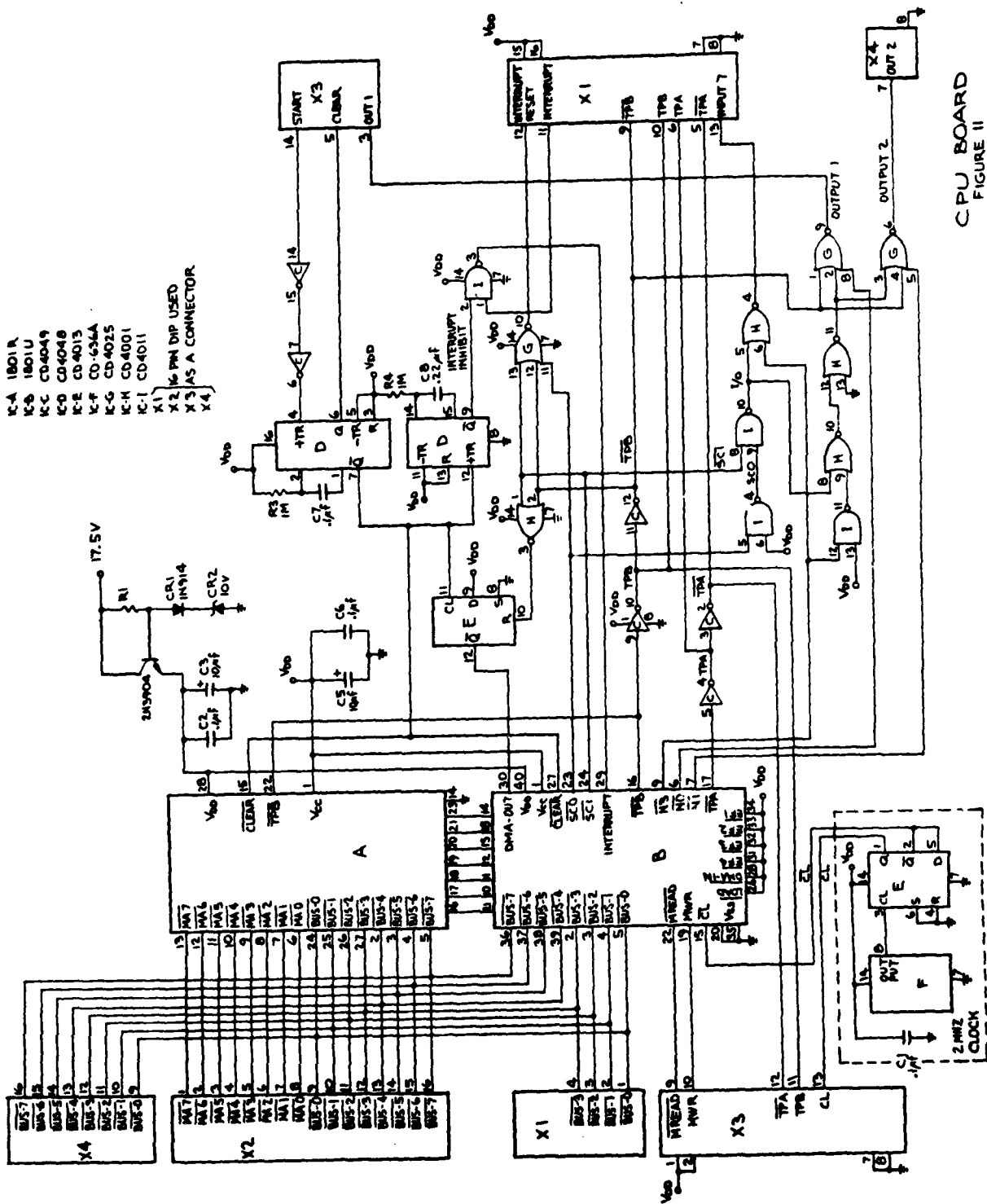
MEMORY BOARD
FIGURE 9

1 2 3 4 5 6 7 8 9 10

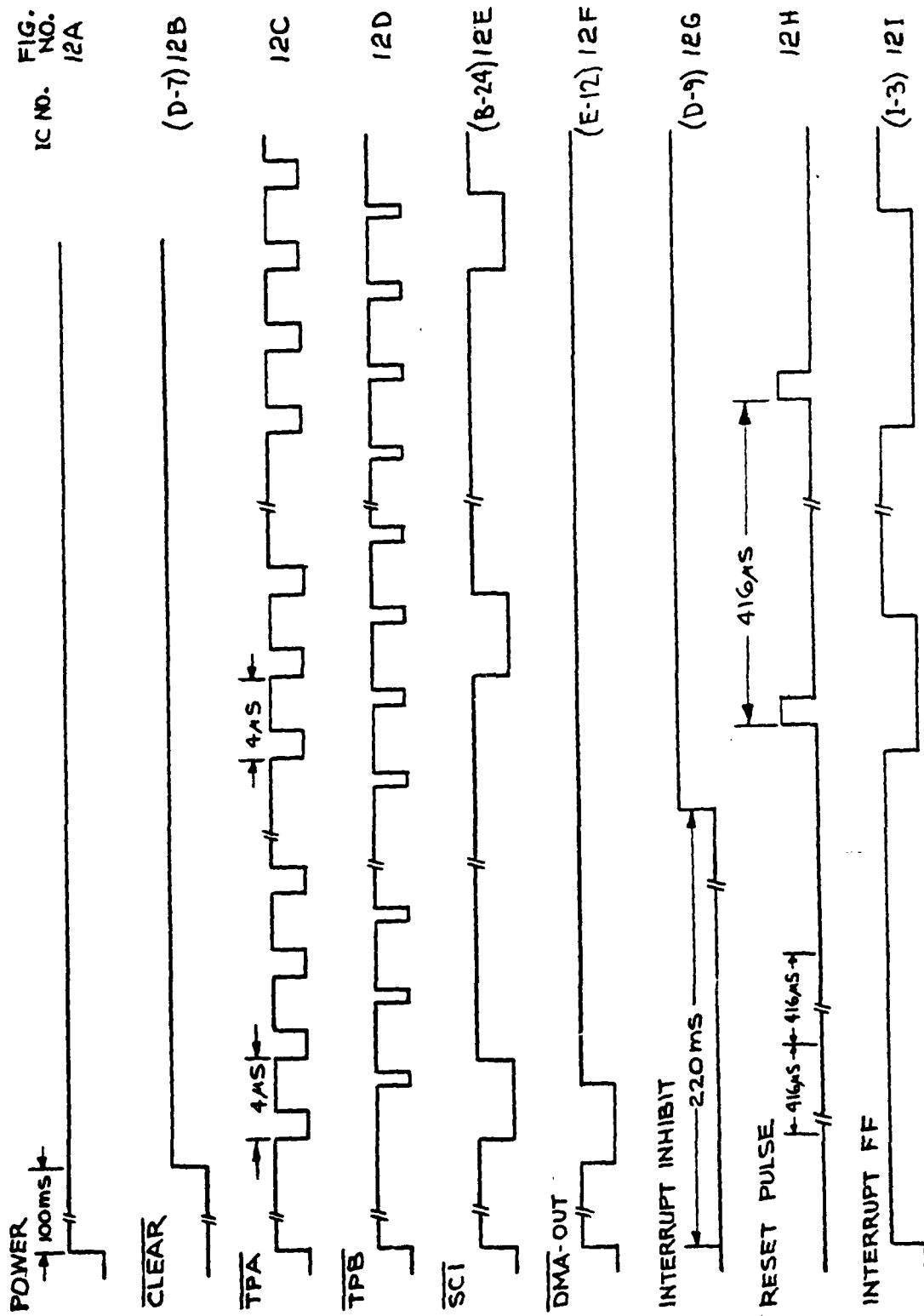
FIG. NO.
IC NO.



MEMORY TIMING DIAGRAMS
FIGURE 10



CPU BOARD
FIGURE 11



CPU CONTROL START SEQUENCE AND INTERRUPT
FIGURE 12

pulse is created to prevent interrupts during COSMAC register initialization. Also a DMA-OUT request is initiated to get the processor out of the IDLE state that the clear pulse puts it in. The DMA-OUT request flip-flop is reset as soon as the request has been operated on by the processor.

Interrupt control is performed by the same counter that controls the DELTIC correlator, IC-A of Figure 6. Every 416 usec, the interrupt request FF, IC-B1 of Figure 6 is set for an interrupt. Within the next eight usec (two machine cycles), the interrupt request is serviced by the processor, indicated by $\overline{SC1}$ and the request FF is reset.

Input-output control consists of decoding the state code ($\overline{SC0}$ and $\overline{SC1}$) and I/O lines ($\overline{NO-N3}$) of the processor to determine if the instruction is an input or output command, and if it is, which input or output instruction it is.

When the processor is ready to read the correlation sum (an INPUT instruction), the input line (IC-H4) enables the tristate buffers IC-M of Figure 6. This allows the new sum in the correlation counter latch to be transferred to memory by the input instruction.

The two output instructions used, OUT 1 and OUT 2, control the output display and printer. During the output command, the processor puts an 8-bit word on the bus line and clocks the information into the appropriate latch; OUT 1 clocks the byte into the output data register and OUT 2 clocks the binary information into the printer interface latch.

Output Display. The output display consists of LED drivers and multiplexing circuitry for the display LED's. There can be a total of 64 LED's that correspond to as many ID numbers. The

display is divided into an eight by eight matrix with the columns multiplexed on and off as the row information is changed accordingly. The schematic of the output board is shown in Figure 13.

The row information is clocked into the output row data register (IC-A) with the OUT 1 instruction. Each bit of the 8-bit word corresponds to one ID number. If the bit is a zero, the LED is on; if the bit is a one, the LED is off. IC's C and D of Figure 13 are the transistors for the LED row drivers (IC-ØT0,...ØT7).

The LED column drivers (transistors DRO...DR7) are enabled by the 8-bit column counter (IC-B) that is advanced one count with the same clock pulse that latches the row information. At each clock pulse (an OUT 1 instruction), one column driver (IC-F) is enabled, which supplies a ground path (through the LED column driver) for that row of LED row drivers. At the next clock pulse, new information is dumped into the row register and the column is advanced one column. When the counter reaches the count of eight, it is reset to one on the next clock pulse and then cycles through all eight columns again.

The clear pulse at system turn on sets the column counter to the first column for column and row synchronization. The duty cycle of the display LED output is 12.5% and the repetition rate is approximately 200 Hz (determined by software).

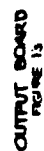


FIGURE 14

| FL | LCC | COSMAC CODE | LYND | SOURCE LINE |
|----|------|------------------|------|--|
| | 0000 | | 1 | ..DISPLAY PROGRAM CONTROLS OUTPUT DISPLAY |
| | 0000 | | 2 | ..MESSAGE PROGRAM FORMATS AND CHECKS DECODED |
| | 0000 | PROGRAM | 3 | .. MESSAGE FOR PROPER INFORMATION |
| | 0000 | ASSEMBLY | 4 | ..INTERUPT PROGRAM DECODES CORRELATED INCOMING |
| | 0000 | LANGUAGE | 5 | .. BIPHASE INFORMATION INTO BINARY INFORMATION |
| | 0000 | LISTING | 6 | ... |
| | 0000 | | 7 | ..PROGRAM ALLOCATES REGISTERS AND MEMORY |
| | 0000 | | 8 | .. LOCATIONS AS FOLLOWS: |
| | 0000 | | 9 | ... |
| | 0000 | | 10 | ..R0: 00->0AF DISPLAY PROGRAM POINTER |
| | 0000 | | 11 | ..R1:170->1FF INTERRUPT == |
| | 0000 | | 12 | ..R4:100->0FF MESSAGE == |
| | 0000 | | 13 | ... |
| | 0000 | | 14 | ..R2:150->15F INTERRUPT DATA POINTER |
| | 0000 | | 15 | ..R3:140->147 OUTPUT ROW POINTER |
| | 0000 | | 16 | ..R5:148->14F MESSAGE DATA POINTER |
| | 0000 | | 17 | ..R8:100->13F ID TAG POINTER |
| | 0000 | | 18 | ... |
| | 0000 | | 19 | ..R8: TEMPORARY ROW POINTER |
| | 0000 | | 20 | ..R9: STORES DECODED INCOMING MESSAGE |
| | 0000 | | 21 | ..R6: R6.1--PREAMBLE ZERO COUNTER |
| | 0000 | | 22 | .. R6.0--TIME INTERVAL FROM LAST CORRELATION |
| | 0000 | | 23 | .. PEAK |
| | 0000 | | 24 | ..R7: R7.1--INCOMING MESSAGE BYTE |
| | 0000 | | 25 | .. R7.0--POINTS INTERRUPT PROGRAM BACK TO |
| | 0000 | | 26 | .. MESSAGE OR DISPLAY PROGRAM |
| | 0000 | | 27 | ..R4: RA.1--TEMPORARY ROW DATA REGISTER |
| | 0000 | | 28 | .. RA.0--UPDATE TIME REGISTER |
| | 0000 | | 29 | ..R0: PC.0--DELAY REGISTER(HELPS KEEP DUTY |
| | 0000 | | 30 | .. CYCLE OF MULTIPLEXED OUTPUT |
| | 0000 | | 31 | .. CONSTANT) |
| | 0000 | | 32 | ... |
| | 0000 | | 33 | ..P2 STACK REGISTER INFORMATION |
| | 0000 | | 34 | .. 15F: X AND P OF DISPLAY PROGRAM |
| | 0000 | | 35 | .. 15E: D OF == |
| | 0000 | | 36 | .. 15D: DF OF == |
| | 0000 | | 37 | .. 15C: CORRELATION TOTAL |
| | 0000 | | 38 | .. 15R: -- |
| | 0000 | | 39 | .. 15A: X AND P OF MESSAGE PROGRAM |
| | 0000 | | 40 | .. 159: D OF == |
| | 0000 | | 41 | .. 158: DF OF == |
| | 0000 | | 42 | ..R5 STACK REGISTER INFORMATION |
| | 0000 | | 43 | .. 14F: MESSAGE LENGTH(0-SHORT; <0-LONG) |
| | 0000 | | 44 | .. 14E: PRINTER OUTPUT INFORMATION |
| | 0000 | | 45 | |
| | 0000 | | 46 | |
| | 0000 | | 47 | TIME=R6: MES=R7; ID=R9 |
| | 0000 | | 48 | ORG+NUM1 |
| | 0001 | | 49 | ..REGISTER INITIALIZATION... |
| | 0001 | F850A2A3F875A1 | 50 | +NUM60->R2.0, R3.0;+NUM75->R1.0 |
| | 0008 | F801B1B2B3B5B9BB | 51 | +NUM1->R1.1, R2.1, R3.1, R5.1, R9.1, RB.1, RB.1 |
| | 0011 | 90A6B6A7B7A9B4BC | 52 | R3.1->R6.0, R6.1, R7.0, R7.1, R9.0, R4.1, RC.0, PC.1 |
| | 001A | F801A4F84FA5 | 53 | +NUM1->R4.0;+NUM4F->R5.0 |
| | 0020 | 23F8AF53 | 54 | INT:DECR3;+NUM8F->+ATSP3 |
| | 0024 | B33A2C | 55 | R3.0->+IF>0 GO TO INT |
| | 0027 | F85AA3F85453 | 56 | +NUM5A->R3.0;+NUM54->+ATSR3 |
| | 0020 | F840A3A8F880PAEP | 57 | +NUM4C->R3.0, R8.0;+NUM80->RA.1;SEXB |
| | 0035 | | 58 | .. |
| | 0035 | | 59 | ..DISPLAY PROGRAM |
| | 0035 | | 60 | .. |
| | 0035 | F840APA8 | 61 | DS1: +NUM40->RB.0, R8.0 ..SET ID=64 |
| | 0039 | F80CAA | 62 | +NUM80->RA.0 ..SET UPDATE TIME |
| | 003C | 2BFD | 63 | DS2: DECR:LOX ..CK ID TAG FOR RECENT XMIT |

```

F 003E 3200      64 IF =0 GO TO DS3 ..BR IF TAG=0
0040 FF315P      65 -+NUM1:STR R3 ..SUPT 1 FROM ID TAG
0043 9AF6        66 RA.1->R:1/2
F 0045 F9803000  67 .OP.+NUM8: GO TO DS4..PUT 1 IN TEM ROW REG
0049 9AF6        68 DS3: RA.1->R:1/2 ..PUT 0 IN TEM ROW REG
004B BA         69 DS4: R->RA.1
F 004C 3800      70 IF NDF GO TO DS5 ..BR IF TEM REG NOT FULL
004E 5818        71 STR R8:INC R3 ..STR TEM REG IN DISPLAY REG
0050 F880BA      72 +NUM8->RA.1
0053 E361        73 DS5:SEX R3:OUT1 ..OUTPUT TO DISPLAY
0055 83FF48      74 R3.0->+NUM48 ..CK IF LAST ROW
F 005A 3400      75 IF >0 GO TO DS6 ..BR IF NOT LAST ROW
005A F840A3      76 +NUM48->R3.0 ..SET DISPLAY TO 1ST ROW
005D 5B8B        77 DS6:SEXRB:RB.0->R ..CK IF ID=0
005F 3A3C        78 IF >0 GO TO DS2 ..BR IF ID>0
0061 2ARA        79 DEC RA:RA.0->R
0063 3235        80 DS8:IF =0 GO TO DS1 ..BR IF UPDATE TIME=0
0065 F818AC      81 +NUM18->RC.0 ..SET DELAY TIME
0068 20A03A68    82 DS7: DECRC:RC.0->R:IF>0 GO TO DS7..BR IF DELAY>
006C 3053        83 GO TO DS5
006E ..          84 ..
006E ..          85 ..MESSAGE PROGRAM
006E ..          86 ..
0070 ..          87 ORG+NUM80
0070 CC          88 BEG:IDLE ..WAIT FOR INTERRUPT
0071 97F6P7      89 MES.1->R:1/2:->MES.1
F 0074 3300      90 IF DF GO TO TP1 ..BR IF FRAME MARK IS PRESENT
0076 2730E0      91 DEC MES:GO TO BEG..NO SYNC MARK
0079 ..          92 ... CK MESSAGE LENGTH
0079 FA03        93 TP1:R.AND.+NUM3
F 007A 3200      94 IF =0 GO TO MM
007D FF0355      95 -+NUM3:MM:STR R5..IF 0,SHORT MESSAGE
0080 2700        96 DEC MES:IDLE ..WAIT FOR LSB OF ID
0082 97F6P7      97 MES.1->R:1/2:->MES.1
0085 2700        98 DEC MES:IDLE..WAIT FOR PARITY BIT
0087 97F6P7      99 MES.1->R:1/2:->MES.1
008A ..          100 ...CK PARITY
F 008A F63B00    101 TP2:1/2:IF NDF GO TO TS2
008D 17          102 INC MES ..COUNT NUM OF 1 BITS
008E 3ACA        103 TS2: IF >0 GO TO TP2
008E 87F6        104 MES.0->R:1/2 ..CK IF ODD
F 008E 3300      105 IF DF GO TO RESET1..OP EVEN
008E 97FA3FA9    106 MES.1.AND.+NUM3F->ID.0..MESSAGE ID
008E 255562      107 DECP5:R->+ATSR5:OUT2
008E F86059      108 +NUM60->+ATSR9..SET DISPLAY TIME(5= 1 SEC DISPL
F 008E F03200    109 LDX:IF =0 GO TO RESET1..BR IF SHORT MESSAGE
008E F820A7      110 +NUM 20-> MES.1
008E 97F63BE4    111 TP3:+NUMC->MES.0:IDLE..WAIT FOR EXTRA BITS
008E F6AA        112 MES.1->R:1/2:IF NDF GO TO TP3
008E F800A7E7B6  113 /2:->RA.0
008E 3080        114 RESET1:+NUM0->MES.0,MES.1,TIME.1
008E ..          115 GO TO BEG
008E ..          116 ..
008E ..          117 ..INTERRUPT PROGRAM
008E ..          118 ..
008E ..          119 ORG+NUM170
008E 1242FE      120 RTN1:INCR2:LDAR2:1/2
008E 4270        121 LDAR2:RETURN..TO MAIN PROG.
008E 227822      122 DECR2:SAVE:DECP2..SAVE XAP
008E 5222        123 STRR2:DECR2 ..SAVE 0
F 008E 3300      124 IF DF GO TO X
008E F8003C00    125 +NUM0->R:GO TO X1 ..SAVE DF
008E F8015222    126 X1+NUM1->R:X1:STRR2:DECP2
F 008E 3000      127 GO TO INPUT

```

```

0185
0186 F858A2
0189 42F642
018C 7C
018D 2278225222
F 0192 333C
F 0194 F8033C00
0198 F8C152
0199 FA5CA2
019E
019E 6F
019F 96FFC5
F 01A2 3200
01A4 F0FFC7
F 01A7 3300
01A9 96
01AA 327C
01AC 86FFGA
F 01AF 3300
01F1 16307C
01F4 96
F 01F5 3200
01F7 86FFC3
01EA 38B1
F 01EC FFC43800
F 01C1 FD023800
01C4
01C4 96FC0186
01C8 F830A6
01C9 A716
01CD 327C
01CF 3086
01D1
01C1 86FD0A
F 01C4 3800
F 01C6 FFC33800
01CA 30CB
01CC F0FFD7
F 01CF 3800
F 01E1 303C
01E3 F0FFD2
01E6 33CB
01E8 97F98087
01EC 1730C8
01EF
01EF F800B7A786
01F4 F8B1A4
01F7 3070
01F9

```

```

128 ...
129 RTN2:NUM58->R2.0
130 LDAR2:2:LDAR2
131 RETURN.. TO MESS PROG.
132 DECR2:SAVE:DECR2:STRR2:DECR2
133 IF DF GO TO Y
134 +NUM5->+GO TO Y1
135 Y1+NUM1->+Y1:STRR2
136 +NUM5C->R2.0
137 ...
138 INPUT:INP7 ..INPUT TOTAL
139 Z5:TIME.1->+NUM5 ..CK IF ZERO=5
140 IF +C GO TO DET..BR IF ZERO=5
141 +ATS->+NUM7..SUBT THRESHOLD
142 Z0:IF DF GO TO Z1..BR IF>TH
143 TIME.1->+ ..LOAD ZERO
144 IF +C GO TO RTN1
145 TIME.0->+NUMA
146 IF DF GO TO RESET..BR IF>TMAX
147 T1:INC TIME:GO TO RTN1
148 Z1:TIME.1->+ ..CK FOR 1ST ZERO
149 IF +C GO TO Z2..BR IF 1ST ZERO
150 TIME.0->+NUM3
151 IF MINUS GO TO T1..BR IF<TMIN
152 -+NUM4:IF MINUS GO TO RESET..BR IF<TWINDOW
153 -+NUM2:IF MINUS GO TO RESET..BR IF>TMAX
154 ...
155 Z2:TIME.1->+NUM1->TIME.1..ADD 1 TO ZERO
156 SYNC:NUM0->TIME.0
157 S2: MES.0->+INC TIME..ADD 1 TO TIME INTERVAL
158 IF +C GO TO RTN1
159 GO TO RTN2
160 ...
161 DET:TIME.0->+NUMA..IS TIME IN WINDOW
162 IF MINUS GO TO RESET..BR IF >TMAX
163 -+NUM3:IF MINUS GO TO D1..BR IF >TWINDOW
164 GO TO S2 ..RETURN
165 D1:+ATS->+NUM7 ..CK FOR +PEAK
166 IF MINUS GO TO D2..BR IF NOT>TH
167 GO TO NEW ..A 0 BIT
168 D2:+ATS->+NUM2..CK FOR -PEAK
169 IF DF GO TO S2..BR IF NOT <-TH
170 MES.1.OR.+NUM8->MES.1..A 1 BIT
171 NEW:INC MES:GO TO SYNC
172 ....
173 RESET:NUM0->MES.1.MES.0.TIME.1..RESET SYSTEM
174 +NUMB1->R4.0
175 GO TO RTN1
176 END

```

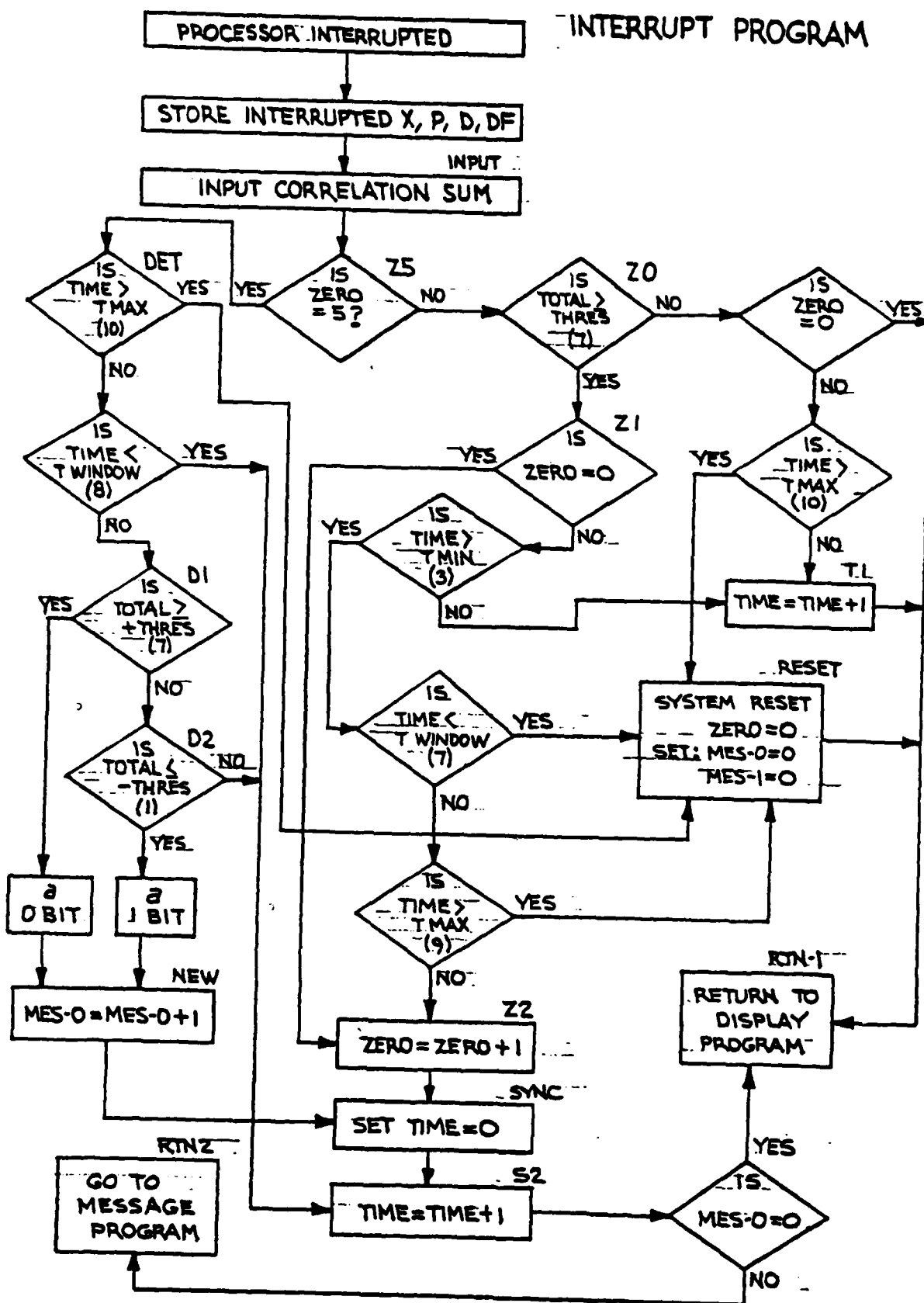


FIGURE 15

Decoder Software

The software is organized as three major programs: (1) the interrupt program which does the actual decoding of the correlated information, (2) the message program that checks the decoded binary data for the proper information, and (3) the display program which updates and controls the output display.

The assembly language listing of the programs along with comments and the assembly code is shown in Figure 14. Descriptions of each program will be discussed.

Interrupt Program. The interrupt program does the actual decoding of the correlated biphasic data. An interrupt is created every 416 usec. At this time, the processor automatically jumps to the interrupt program (IP) where the most recent correlation sum is transferred to memory. Using the new sum, the IP checks for a correlation peak and the time interval from the last peak. The program determines from this information if the incoming data is biphasic information or if the input signal is random noise. Depending on the results of these tests, the program sends the processor to either the display program or message program. The flow diagram of the interrupt program is shown in Figure 15.

At the time of the interrupt, the IP stores the information necessary to return the processor to the exact point from which it was interrupted. When this is done, the correlation sum is transferred to memory by the input instruction. The program is now at pt Z5 of the flow chart.

There are several paths that the IP can take depending on the value of the correlation sum (TOTAL), the preamble zero counter (ZERO), and the time interval counter (TIME). The

preamble zero counter keeps track of how many biphase zeros are received in a row. The time interval counter is the elapsed time (number of interrupts) from the last correlation peak (a correlation peak being a correlation sum of 7 or 8 coincidences).

Referring to Figure 15A, assuming random noise as an input signal and $ZERO = 0$, the two paths that can be taken are shown. If $TOTAL < 7$, the processor returns to the display program (DP). If $TOTAL \geq 7$, it appears as if a biphase zero has been received and $ZERO$ is increased by one at pt Z2, $TIME$ is set to one at pt SYNC, and the program returns to the DP.

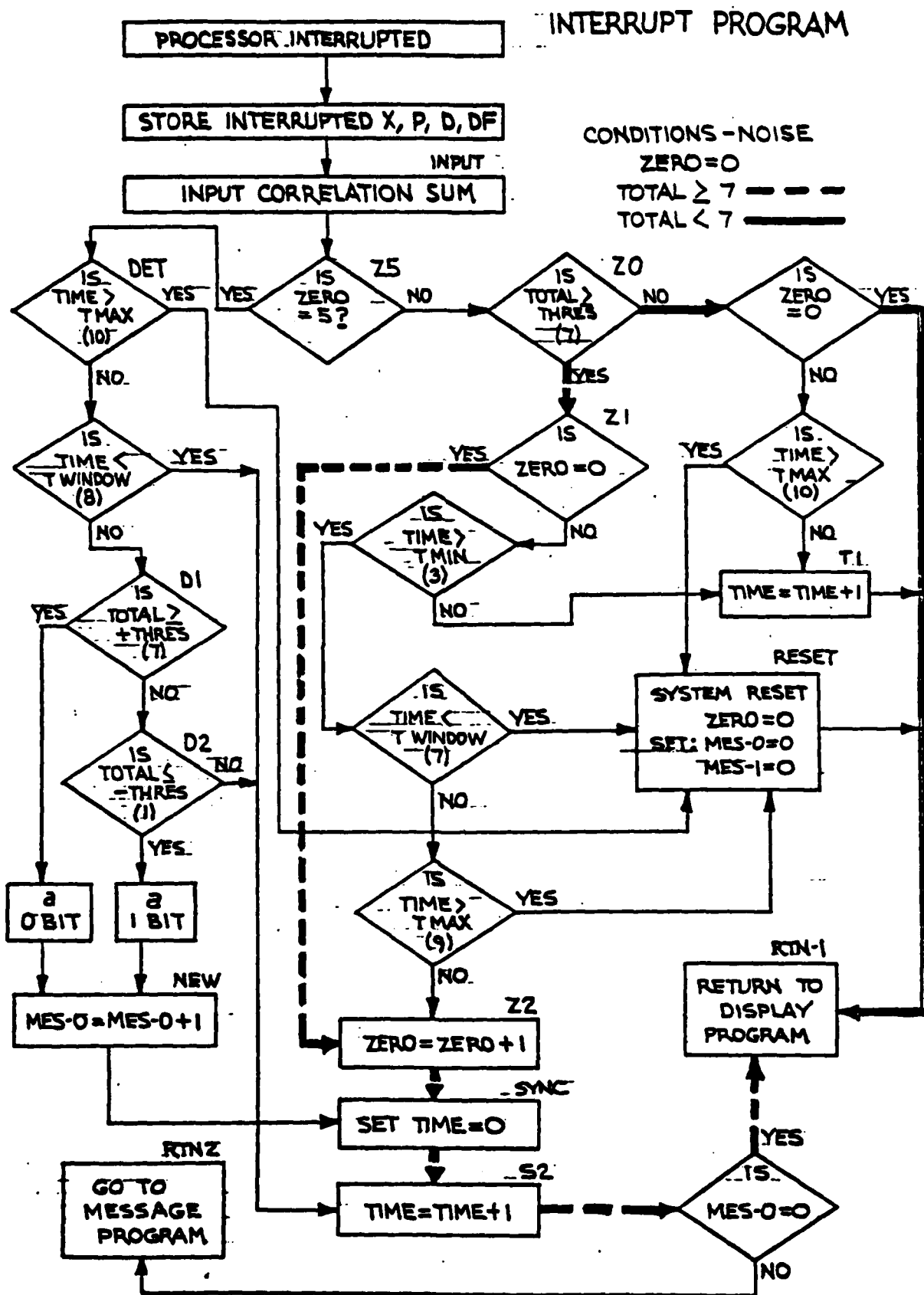
During the next several interrupts Figure 15B illustrates the paths that will be followed if the input signal is still noise and $TIME < TMAX$, $TMAX$ being the maximum time allowed between correlation peaks before the system is reset.

For the case where $TOTAL < 7$, $TIME$ is increased by one at pt T1 and the program returns to the DP. If $TOTAL \geq 7$, a peak has occurred before it should for a biphase zero (indicating noise) and the system is reset and returns to the DP.

Figure 15C shows the two paths that are followed if $TIME > TMAX$, again indicating noise. In both cases, the system is reset and returns to the DP.

Now considering the case where a valid message is being received, Figure 15A ($TOTAL \geq 7$) shows the path that results from the first biphase zero received from the preamble.

For the next four biphase zeros that are detected, Figure 15D illustrates the flow of the program. The $TOTAL < 7$ path will be followed until $TOTAL$ is again ≥ 7 , $TIME$ being increased by one each time this route is taken.



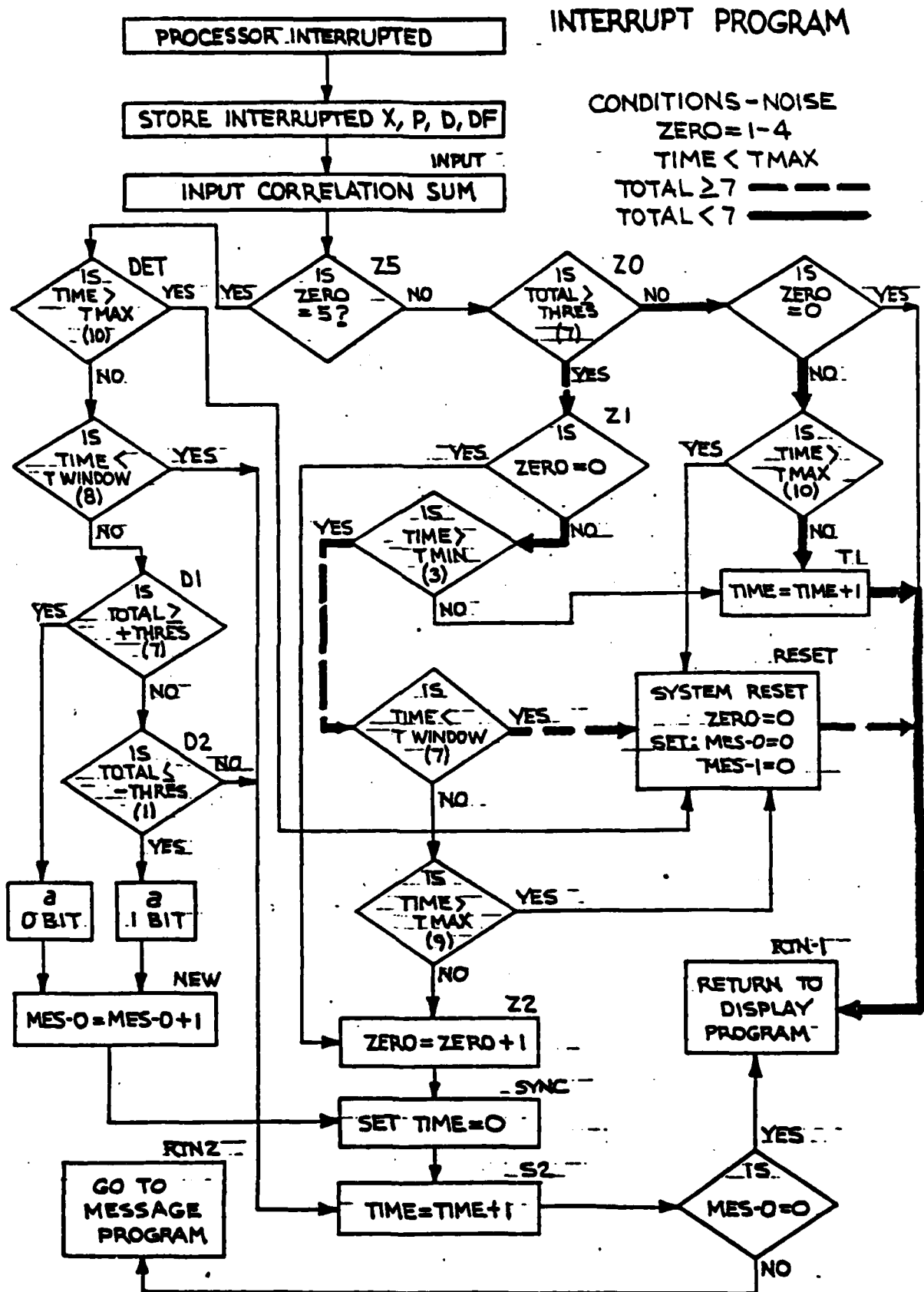
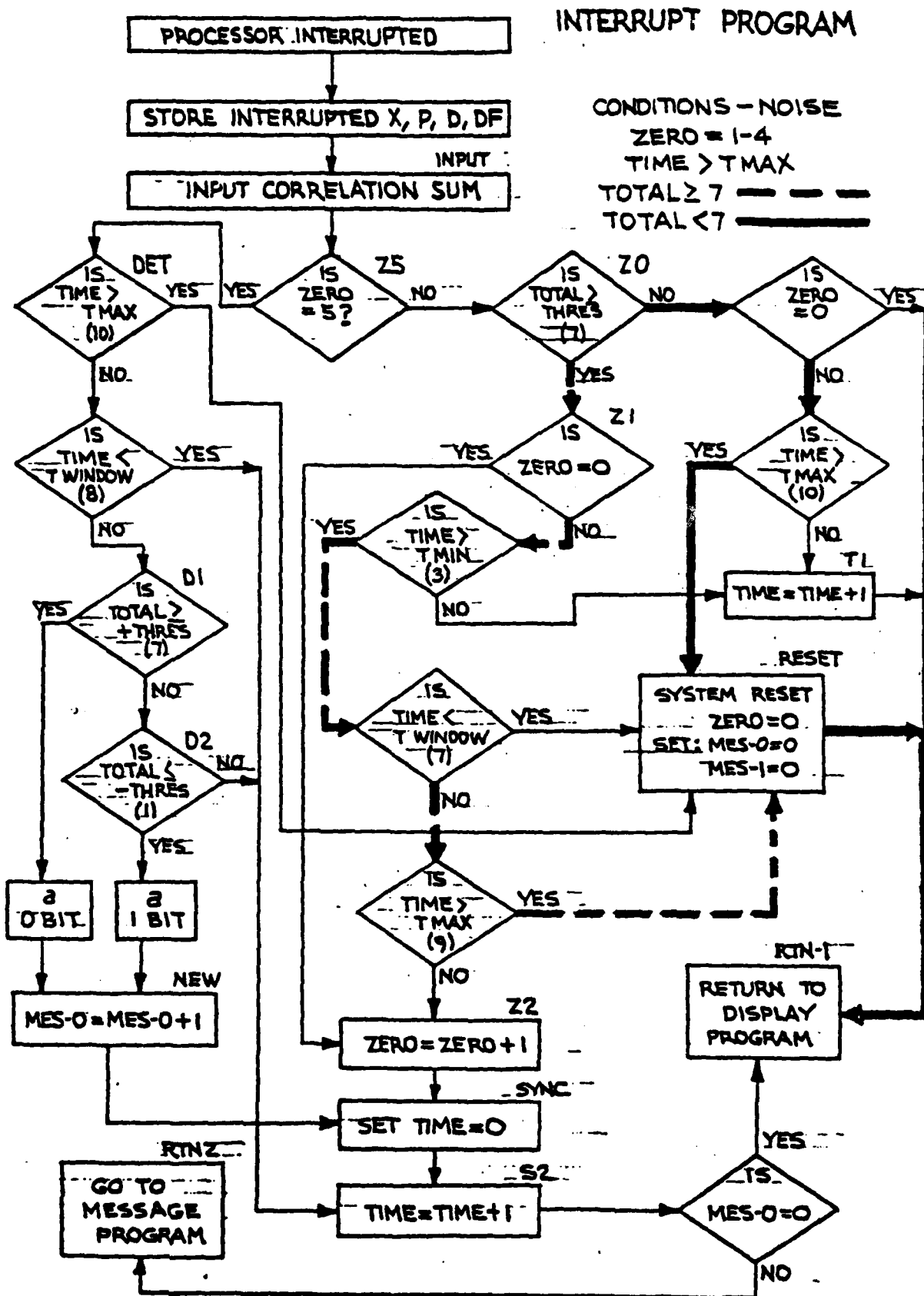


FIGURE 15B



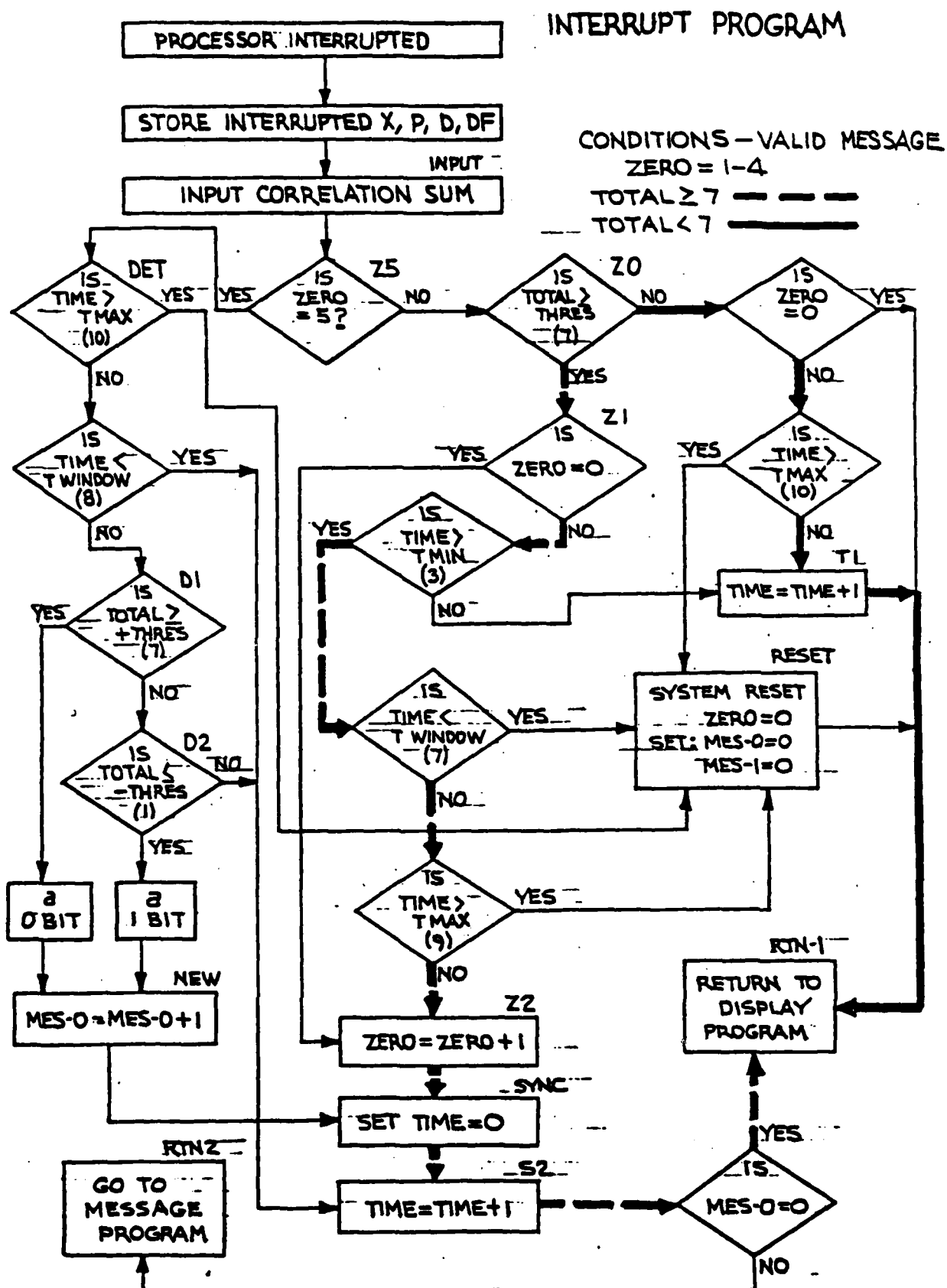


FIGURE 15D

Ideally, a correlation peak should occur when $TIME = 8$. When $TIME$ is 7, 8 or 9, allowing for a noisy signal, $TOTAL$ should be ≥ 7 . $ZERO$ will be incremented by one and $TIME$ will be set to one at pt SYNC. This process will be repeated for the first five biphase zeros of the preamble.

It is possible the correlation sum will remain above the threshold for two or maybe three sample periods because of noise. If this occurs, the Z0-Z1-T1 path will be taken for the second and third cycle instead of the Z0-T1-T2 path.

When five zeros have been detected, it is assumed a valid message is being received. From this point, the correlation sum is tested only during the proper time interval ($TIME = 7, 8, \text{ or } 9$). Figure 15E demonstrates the flow of the program once the preamble has been recognized. If $TIME < 7$, $TIME$ is incremented by one and the processor returns to the DP. When $TIME \geq 7$, $TOTAL$ is checked for a positive or negative peak. If there is no peak, $TIME$ is incremented by one and the processor returns to the DP.

Figure 15F assumes there is a correlation peak in the proper time window, a positive peak indicating a zero bit and a negative peak being a one bit. This information is stored in the memory message register, MES 1. The program pointer, MES 0, is set to one at pt NEW which will direct the processor to the message program (MP) after $TIME$ is set to one at pt S2.

As the message continues, the program flow should follow the paths of Figure 15E for 7 or 8 interrupts and then the path of 15F to determine if the most recent biphase bit was a binary zero or one.

The message program resets the program pointer, MES 0 to zero when it has finished processing the latest binary bit. This allows the processor to return to the display program as a message is being decoded.

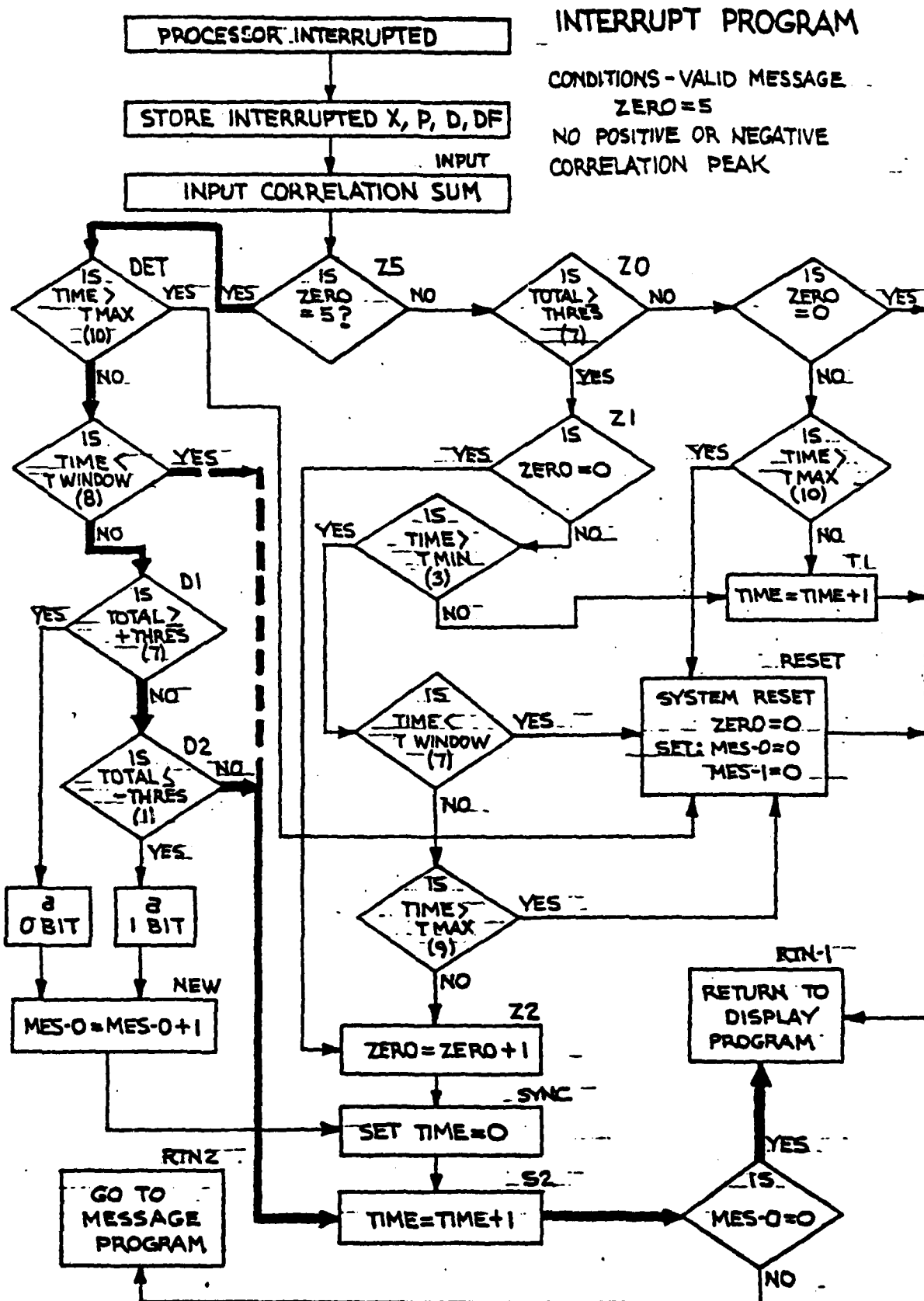


FIGURE 15E

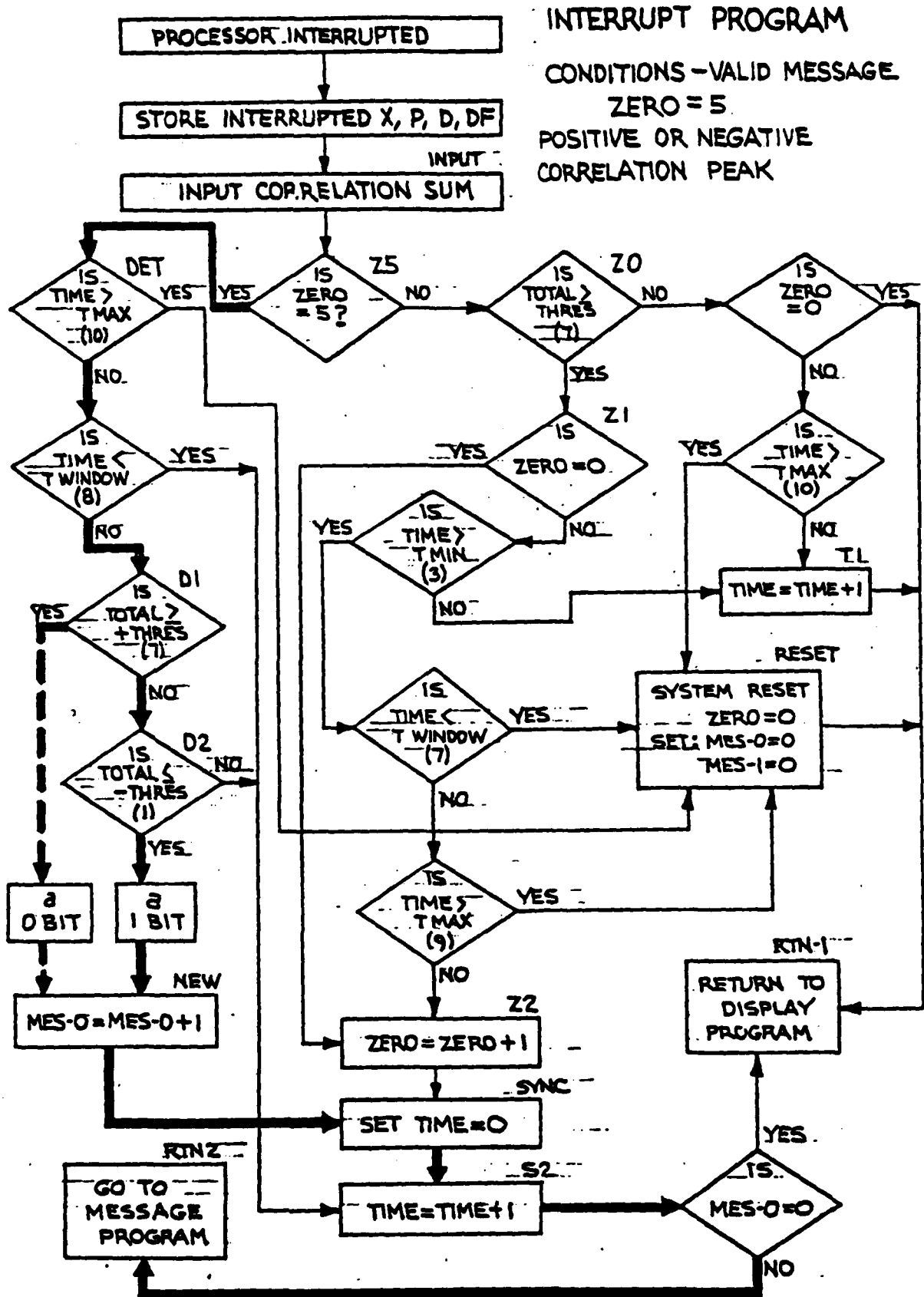


FIGURE 15 F

Message Program. The message program collects the binary information that is stored in the message register MES 1 to determine if the incoming message is a short message (ID number only) or a long message (ID number, plus six additional information bits) and decides if the parity of the ID is correct. Once the message has been determined valid, the appropriate ID memory location is set to tell the display program a valid message has been received and sends the proper information to the printer. The message program (MP) flow chart is shown in Figure 16.

Once the IP has determined a valid message is being received, the IP will direct the processor to the MP each time another biphasic bit has been decoded. The newest binary bit is stored in the MSB of the message register, MES 1 by the IP. When the MP is entered, this register is shifted right one bit, as shown in Figure 17A. As the register is shifted right, the right most bit of the register is put into the DF register. This register is checked for the frame marker, a binary one. If the frame marker is not in the DF register, the program will reset the program pointer, MES 0, and return to pt BEG.

The processor will remain at this point until it is again interrupted and jumps to the IP.

Every time the MP is entered, which will be every eight or nine interrupts as a valid message is being received, a new bit has been decoded and the data in the MES 1 register is shifted right one bit, illustrated in Figure 17A, B, C. This will continue until the frame marker is shifted into the DF register, Figure 17D. With the frame marker in DF, the program will check the message length (pt TPl of the flow diagram), reset the program pointer to zero, and wait at this point for the next interrupt.

MESSAGE PROGRAM

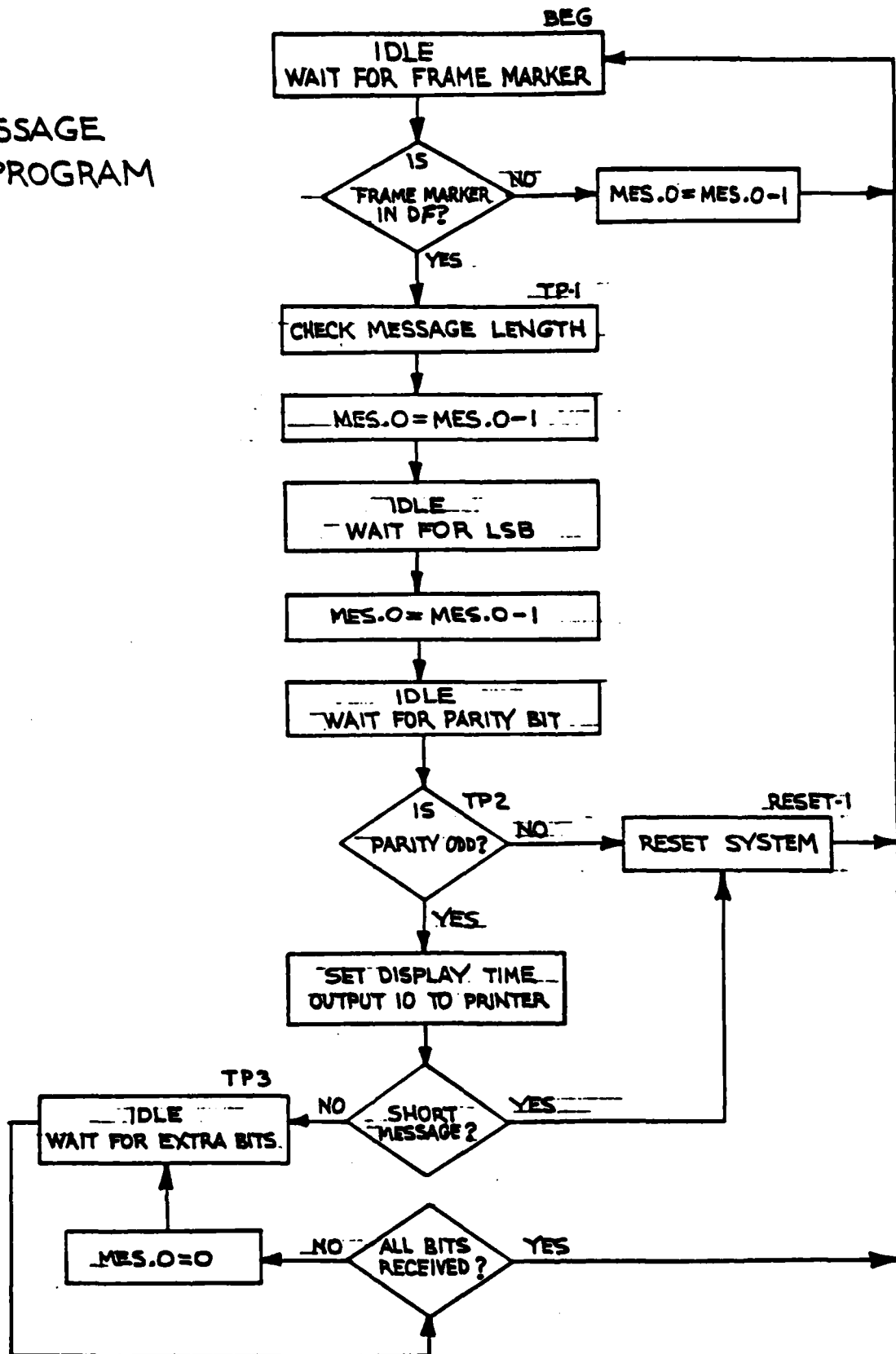


FIGURE 16

MESSAGE REGISTER (MES.1)

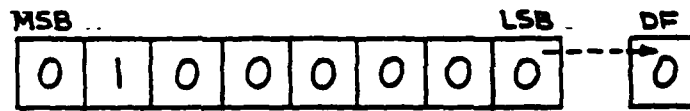
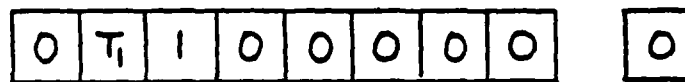
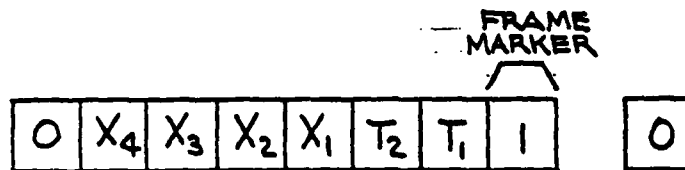


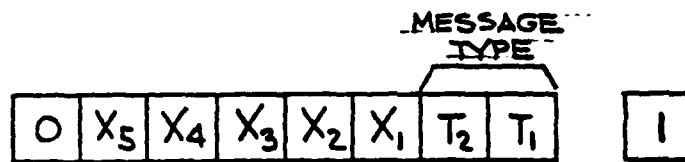
FIGURE NO.
17A



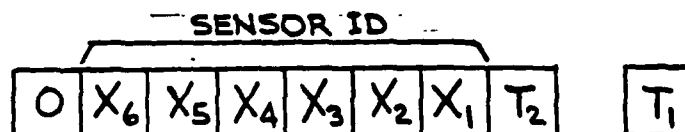
17B



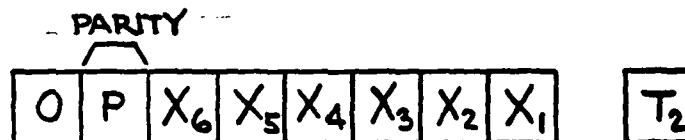
17C



17D



17E



17F

ILLUSTRATION OF DATA FORMATION
OF INCOMING MESSAGE
FIGURE 17

The next two bits that are received are the MSB of the ID and the message parity bit (Fig 17E, F). When the parity bit has been received, the parity of the message is tested at pt TP2. If parity is even, the message is not valid and the system is reset. If parity is odd, the program outputs the ID number to the printer and sets the approximate ID memory location to tell the display program a message has been received. The value of the number (ID tag) stored in the ID memory location determines the length of the display time.

If a short message was transmitted, the program will return to pt BEG. For a long message, the program will wait at pt TP3 for the six additional information bits before returning to pt BEG.

Display Program. The display program (DP) updates and controls the LED display. The flow diagram of the program is shown in Figure 18. There are 64 ID memory locations that are continually checked for recently received messages. The 64 ID memory locations are divided into an 8x8 matrix with each row of the matrix requiring one byte (eight bits) of memory. Each bit of a matrix row byte corresponds to one ID number.

The eight matrix rows are updated five times a second while the rows are multiplexed to the output register at about a 200 Hz rate.

Referring to Figure 18A, the update cycle of the program is shown. At pt DS2, the ID memory location is decremented by one. If it is the first time through the loop, the ID that is tested is ID#63. The ID tag (the value stored at the ID memory location) is checked. If the value is zero, no messages have been received with that ID and a zero is put in the temporary display register (A.1) at that ID's bit position.

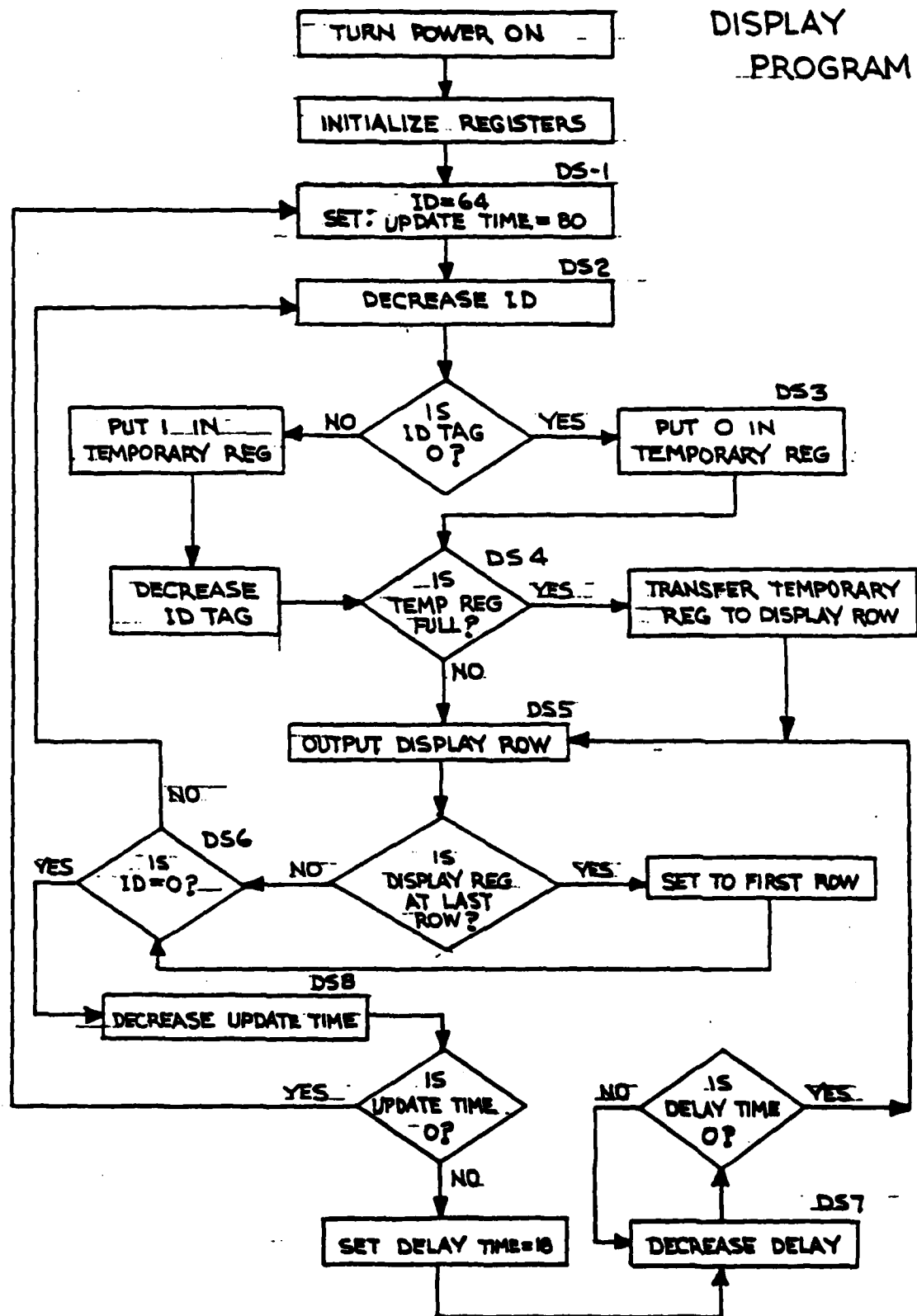


FIGURE 18

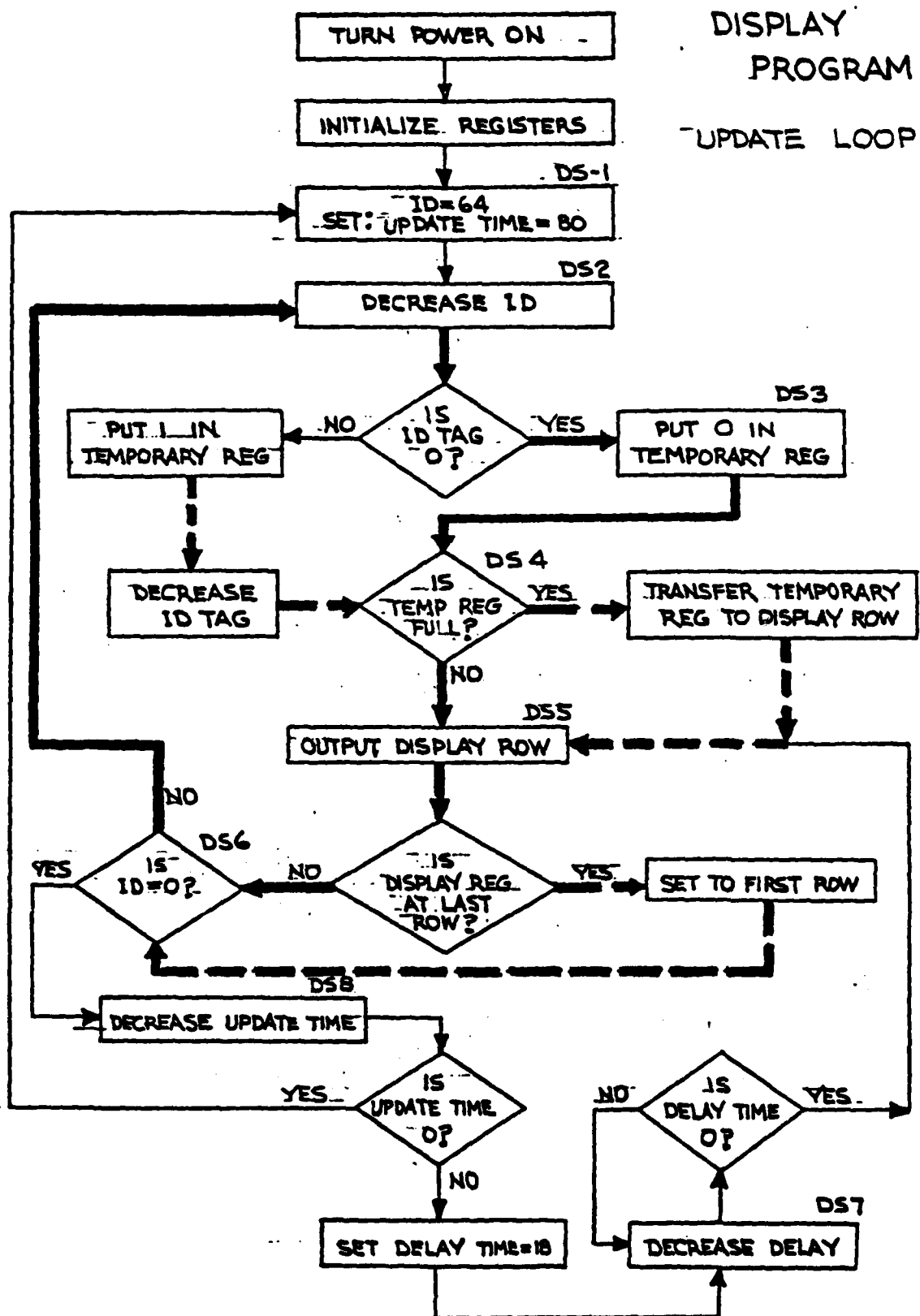


FIGURE 18A

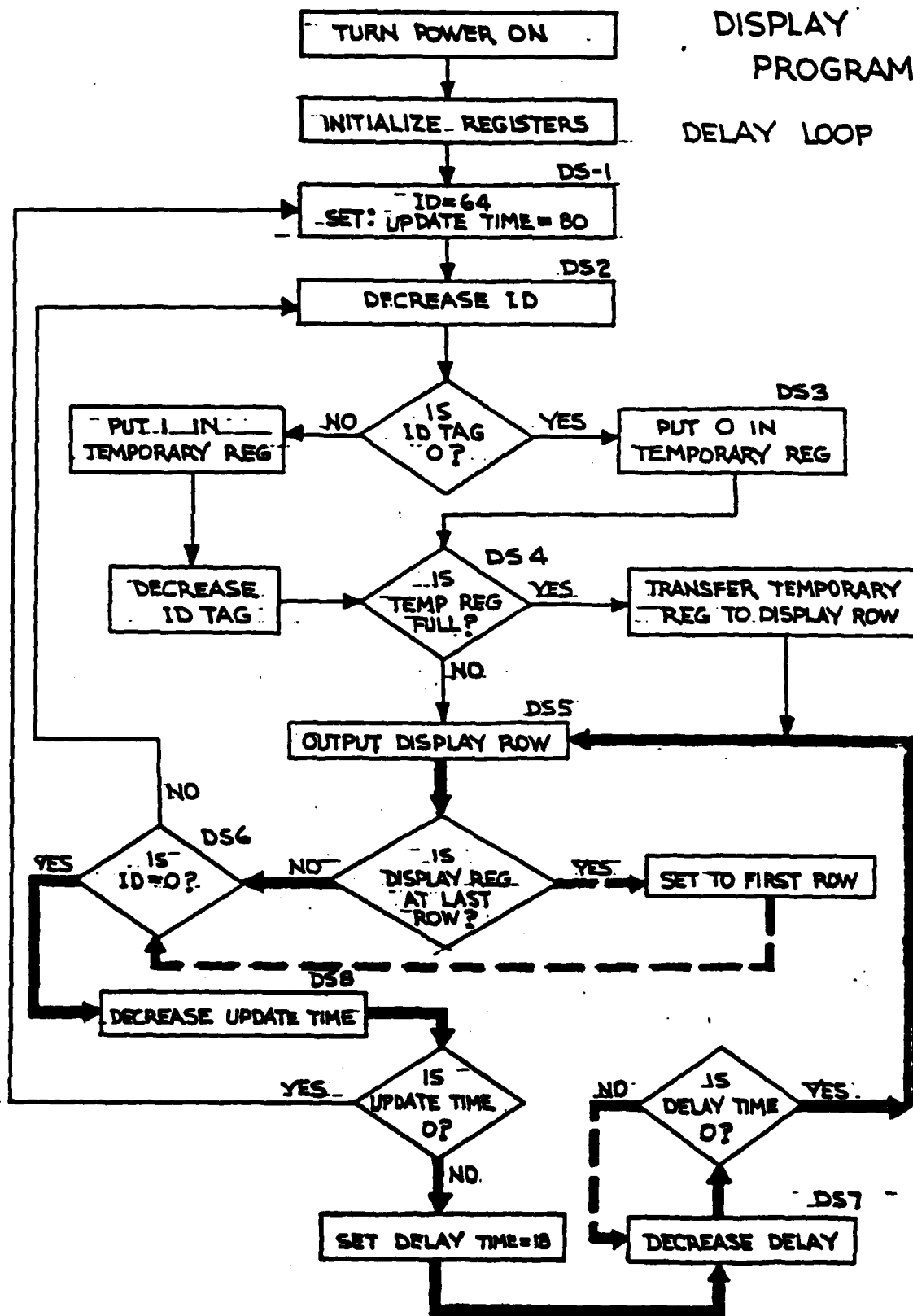


FIGURE 18B

The next time through the loop, ID#62 will be tested. If the ID tag has a value greater than zero, a one will be stored in the temporary display register and the ID tag will be decreased by one. This will continue for each cycle through the loop until a position bit, indicating the temporary register is full, is in the DF register. The contents of the temporary display register is transferred to the output display row memory location. An example illustrating the above procedure is shown in Figure 19.

The next eight ID locations will be tested in the same manner and the contents of the temporary display register will be stored in the next display row. This will continue until all 64 ID memory locations are tested.

Each time an ID memory location is checked, the value (if > 0) of the ID tag is decreased by one until its value is zero. Since the ID tags are checked approximately five times a second, a value of five for the ID tag will turn on the LED display light corresponding to the ID number for about one second.

During each cycle of the update loop, an output display row byte is transferred to the output display register by the OUT 1 instruction (pt DS5 on the flow diagram). If the last row has just been transferred to the output, the display row pointer is set to the first row. The program will step through the eight output rows during the next eight cycles of the update loop.

The update loop will continue until all 64 ID memory locations have been tested. Once this is completed, the program will begin the delay loop, illustrated in Figure 18B.

The delay loop controls the 200 Hz multiplexing rate of the LED display. The multiplexing is not a constant rate because the interrupt program will vary in time depending on the incoming data.

| | | TEMPORARY DISPLAY REGISTER | | | | | | | | | |
|-------------------------|--------|----------------------------|--------------|----|----|----|----|----|-----|----|-------------------|
| CYCLE OF UPDATE LOOP | | MSB | POSITION BIT | | | | | | LSB | DF | OUTPUT ROW NO. |
| | | | | | | | | | | | |
| 1 | | 63 | 1 | - | - | - | - | - | - | 0 | - |
| 2 | | 62 | 63 | 1 | - | - | - | - | - | 0 | - |
| 3 | | 61 | 62 | 63 | 1 | - | - | - | - | 0 | - |
| 8 | ID NO. | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 1 | 1 |
| 16 | ID NO. | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 1 | 2 |
| 24 | ID NO. | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 1 | 3 |
| 32 | ID NO. | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 1 | 4 |
| 40 | ID NO. | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 1 | 5 |
| 48 | ID NO. | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 1 | 6 |
| 56 | ID NO. | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 1 | 7 |
| 64 | ID NO. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 8 |

FORMATION OF OUTPUT DISPLAY ROWS
FIGURE 19

A varying multiplexing rate causes the output LED's to flicker when turned on. The delay loop lengthens the time between output instructions (which determines the multiplexing rate) so the varying rate caused by the interrupt program is not as noticeable.

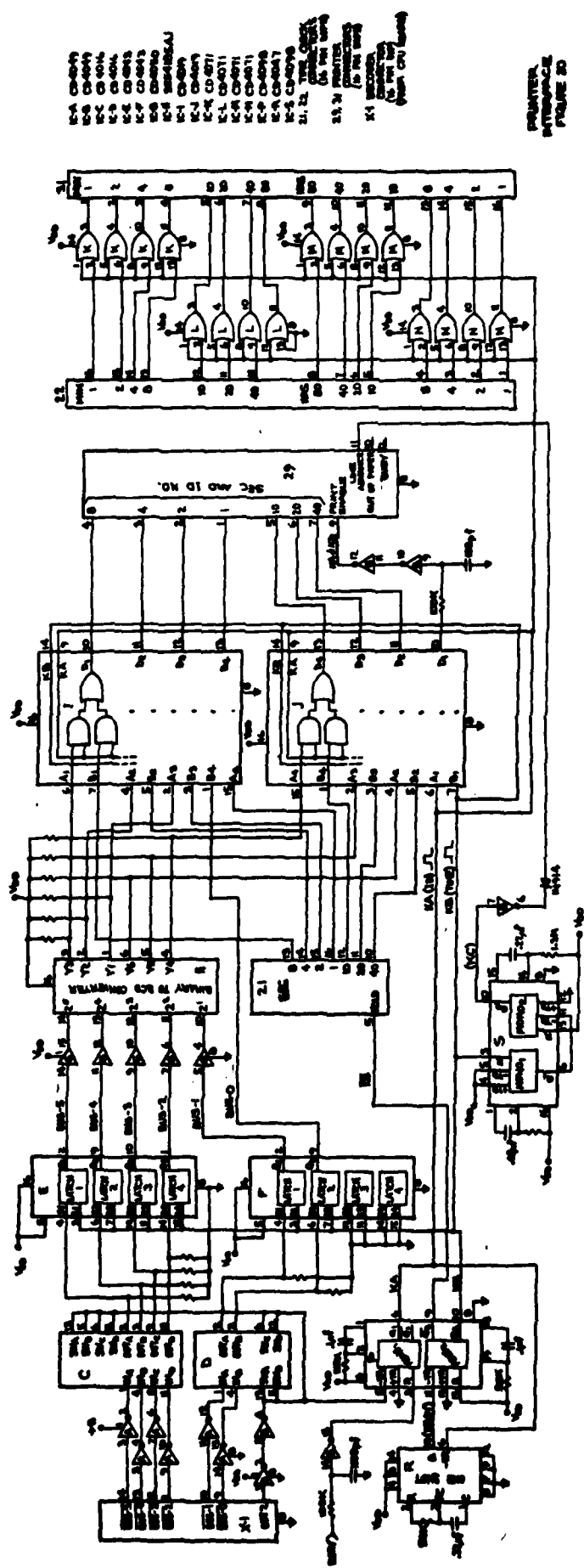
The length of time the display program will remain in the delay loop depends on the value of the update constant. During each cycle of this loop, the update constant is decreased by one at pt DS8. The delay loop will continue until the update constant is zero, allowing the program to enter the update loop again. With a value of 128 for the update constant, the update loop is entered about five times a second.

The update constant was an arbitrary value picked to allow some flexibility in the setting of the display time and still have the ID memory locations updated at a reasonable interval. The delay constant (pt DS7 on flow diagram) was chosen to reduce the flicker of the display LED's.

Peripheral Circuits

Printer Interface. The printer interface is necessary to convert the binary ID data the microprocessor outputs to BCD information required by the printer. The interface circuits also multiplexes the converted ID code and the clock BCD code onto the printer BCD input lines. The schematic of the printer interface is shown in Figure 20.

When a message has been received, the binary ID code is clocked into the printer interface latches (IC-E,F) by the OUT 2 instruction. The bus lines and command line are buffered (IC-C,D) to the printer operating voltage of five volts. The latched information is converted to BCD code and then routed to the printer multiplexing logic (IC-I, J). The latched outputs are buffered (IC-G) to drive the TTL binary to BCD converter (IC-H).



The printer can print six digits and therefore require 24 BCD input lines. The two least significant digits are used for the ID number or seconds of the time and the remaining four digits are used for minutes and hours.

When the binary ID information is clocked into the latches, the same clock pulse creates the ID print pulse KA (IC-P6) that will command the printer to print the ID number. The KA pulse also creates an invalid input (all ones) for the four most significant digits thereby blanking them out.

A minimum time of 330 ms is necessary for the printer to complete one line. This delay is produced by IC-R. When the printer is ready to print the second line, pulse KB (IC-P10) transfers the clock BCD output to the printer input lines (IC-I, J, K, L, M, N). IC-S creates another delay for the printing of the time and then advances the printer one line with pulse KC (IC-S10).

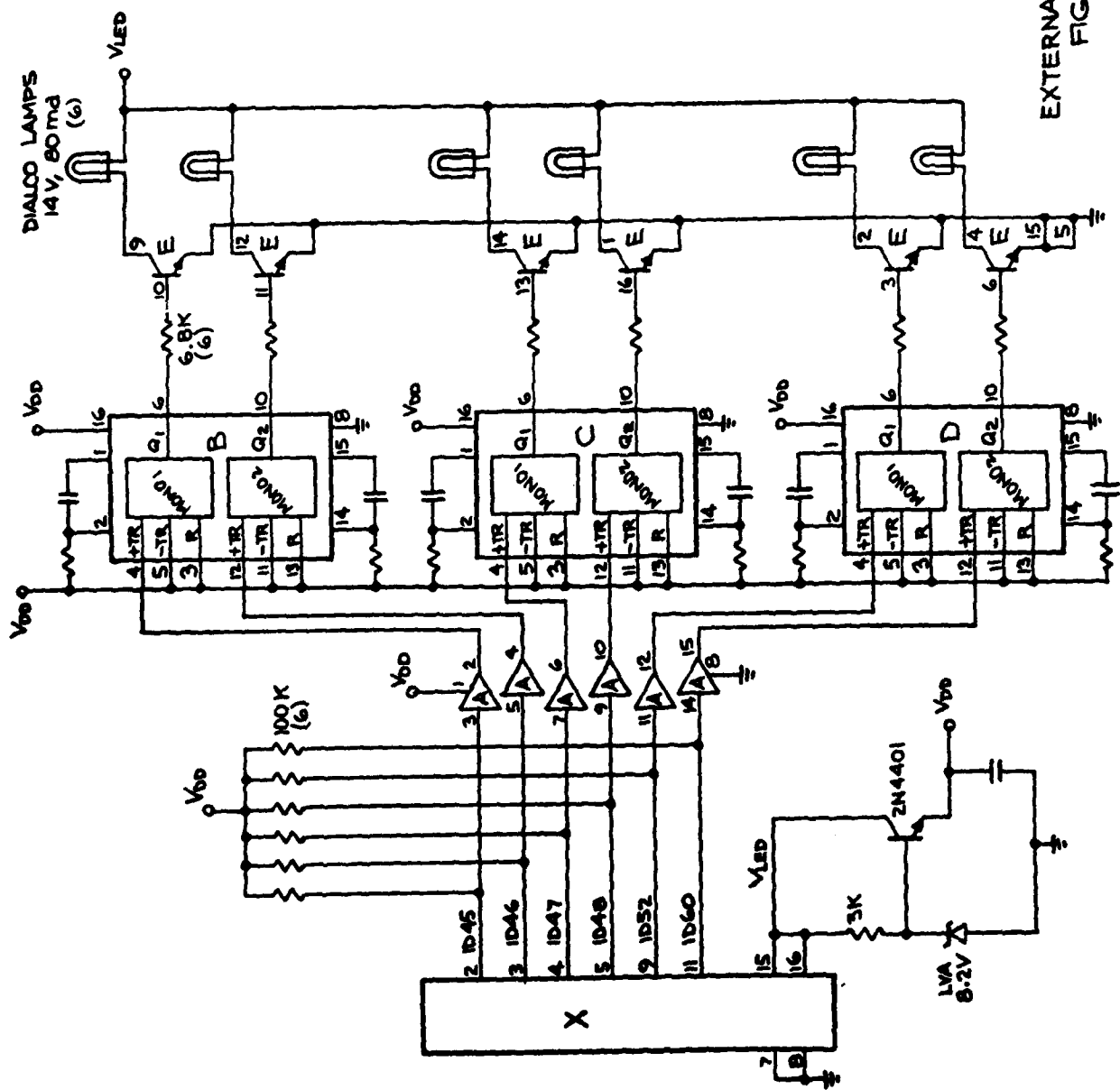
The printer output, BUSY, inhibits another ID to be printed before the above sequence is finished. One ID and related time can be printed per second.

External Lamp Drivers. In addition to the display LED's, there are display lights external to the display box. Incandescent lamps and drivers are needed because the LED's do not produce enough light if viewed from many different angles.

Miniature incandescent lamps are used because of their better visibility at greater angles of view. The multiplexing rate of the LED's is not sufficient to illuminate the miniature lamps; therefore, the need for non-multiplexed drivers. The schematic is shown in Figure 21.

To accomplish the non-multiplexing of the lights, one-shots (IC-B,C,D) of a length longer than the multiplexing rate are used

to turn on the lamp's transistor drivers (IC-E). If the display LED is multiplexed on, the one-shot will be triggered at the multiplexing rate and provide the lamp drivers with a continuous ON signal for as long as the LED is pulsed ON and OFF.



IC-A CD4050B
 IC-B CD4098
 IC-C CD4098
 IC-D CD4098
 IC-E CA3081
 X DISPLAY CONNECTOR
 (16 PIN DIP)

EXTERNAL LAMP DRIVERS
FIGURE 21

APPENDIX B

REMOTE VESSEL MONITORING SYSTEM (RVMS)

1. GENERAL DESCRIPTION

a. The RVMS utilizes a magnetic detector to signal the presence of ships within its detection envelope. The information is relayed via a VHF-FM link to the Vessel Traffic Service (VTS) where it is displayed and recorded.

b. The system consists of a magnetic detector enclosed in a waterproof housing connected to the above water transmitting station by a waterproof cable. The transmitting station is housed in an AN type shipping container 10.5' in diameter and 42' long. Inside the container are the transmitter, encoder, message identification selector, and battery pack. The antenna is attached to the outside of the container and is indistinguishable from the container.

c. At the VTS duty room, the messages from the detectors are received, decoded, and recorded. A receiving antenna is located about 130 feet above sea level on a tower at the VTS. A cabinet containing the receiver, decoder, printer and digital clock is located near the watch supervisor's station. Each time a vessel triggers a magnetic detector, the printer indicates the time of occurrence and the location of the activated detector. Transmitting stations are located on Navigation Aids (NA) and the detectors are placed near the edge of the ship channel adjacent to the NA. This was necessary to insure sensor integrity during dredging operations.

2. COMPONENT DESCRIPTIONS

a. Receiver/Display Unit

(1) Antenna - A corner reflecting antenna with 10 dB gain, 30 dB front-to-back ratio, and a beam width of 40° was mounted on the VTS tower atop the duty room. Estimated height above sea level is 130 feet, providing a nautical mile line of sight range of 1.4 130 ft or 16 nm to an antenna at sea level. Range to the farthest NA (146) is 6 nm. No problems were encountered with the RF transmission path. The antenna was connected to the receiver through 200 feet of RG 213 coaxial cable. Type N male coaxial connectors are used on both ends of the cable. The cable has an attenuation at 200 MHz of 3 dB/100 ft.

(2) Receiver - The receiver is a commercial VHF-FM 6 channel crystal controlled radio operated at 168.0625 MHz. Sensitivity is -100 dBm for 20 dB quieting. An audio bandpass of at least 3 kHz is required. The remote station signal is taken off the discriminator for processing. This allows the squelch and volume controls to be set for operator convenience without affecting operation of the decoder.

(3) Printer - The digital printer is activated each time a message is received from a transmitter. The printer indicates the time of receipt and the number of the NA the message originated from.

(4) Digital clock - The clock is used to provide the printer with real time for the printout. Clock outputs are directly compatible with the printer input requirements.

(5) Decoder - The decoder utilizes the RCA CDP 1801 microprocessor to decode the digital signal output from the receiver. The remote transmitter message is decoded and the NA number is printed along with the time of receipt. Small LED's on the front panel of the Receiver/Display unit are activated for 20 seconds each time a message from a NA location is received. The six LED's can be connected to represent any of the 64 NA numbers available. Connected in parallel with the LED's are small incandescent lights located on the VTS plotting board so that duty personnel can readily compare a vessel's dead reckoned position with the actual position.

b. Transmitter Unit

(1) The housing consists of a 10.5" diameter by 42" high AN type metal shipping container. A lucite platform is bolted across the diameter of the can 18" from the open end. The platform supports the battery pack and transmitter/encoder/NA number selector assembly.

(2) The transmitting antenna is a magnetic microstrip dipole commonly known as a quarter-wave patch radiator. It is a thin, conformal antenna which is easily camouflaged. The antenna is produced on a piece of copper clad teflon-fiberglass substrate 1/32" thick through a combination etching and plating process. After being riveted to the outside surface of the can, the antenna is coated with Epon 828 between 8 and 10 mils thick to provide protection against weather. It is then spray painted white to match the rest of the can. The antenna is 12.25" wide by 8.0" high and is horizontally polarized. Impedance is 50 ohms. VSWR is very sharp and is 1.5:1 or less at the transmitting frequency.

(3) The transmitter/encoder/NA number assembly receives a 6-volt, 5 ms pulse from the magnetic detector and sends an FSK transmission of an 18-bit word containing the NA number. The NA number is selected by setting the eight switches on the code board module. This binary word is fed to the encoder which actually modulates the transmitter. The transmitter is activated for 60 ms with each transmission and will not interfere with other RF transmissions. Nominal RF output is 4.0 watts with a supply voltage of 30 volts.

(4) The battery pack consists of 25 Mallory mercuric oxide D size cells connected in series to give 36 volts open circuit. These cells are specially made by Mallory to provide long life at low standby current with the capability of providing 600 ma transmitter current pulses without a drastic drop in voltage. Under these load conditions, and at 70°F, rated capacity is 12 AH. With the high current pulse lasting only 60 ms, the transmitter has little effect on battery life. Expected life with 250 transmissions per day is 172 days while life with no transmissions at all is 179 days. High temperatures, above 100°F, will shorten battery life and low temperature, below 30°F, will decrease load current by 30 percent. Choice of batteries will depend on geographical location. Lead time is normally 30 days ARO from Mallory for the 317745 cell. For colder climates, the new lithium organic cells would be preferred. Circuit requirements are

2.8 ma steady state drain with 630 ma, 60ms, pulses required for each transmission. Minimum transmitter voltage is 21 volts under load (3.7 watts output).

c. DETECTOR HOUSING

(1) The detector is housed in a well cut into a 2" thick aluminum plate along with a circuit board which contains a voltage regulator and output driver circuit. Power for the detector is provided by the battery pack at the transmitter unit. The regulator reduces the 36 volts from the battery to 8.7 volts for the detector. The output circuit is used to modify the detector output signal to match the transmitter turn on signal requirements. The detector circuitry contains a 10 second time constant which precludes output pulses spaced less than 10 seconds apart. A small tug will result in only one signal while a 300 foot ship at eight knots will provide two to four signals at 10-second intervals depending on the ship's distance from the detector.

(2) Magnetic Detector - The detector is the GSQ-180(V) originally developed for use in Vietnam for detection of troops carrying a rifle. The detector consists of a balanced magnetic coil, amplifier, and output circuit. The detector is sensitive only to a changing magnetic field. As long as the earth's magnetic field is not changing with respect to the detector, there is no output. As a general rule the detector will provide an output signal when a change of 10 gamma peak occurs over a 4 second period or 2 gamma peak over a 0.5 second period. (Specification threshold sensitivity is 2.5 gamma p-p at 1.0 Hz). As the distortion of the earth's magnetic field caused by passage of a ship is spherical, the range at which a 2-gamma change can be detected is a cubic function for a given size ship. Range tables for various ship sizes and speeds are not available and would be a rather large effort to obtain. In general, calculations show that a 200 ton ship moving at five to eight knots should be detected at 100 yards, a 1000-ton ship at 200 yards and a 10,000 ship at 400 yards. These extrapolations from other data have never been tested. Results will depend a great deal on the amount of permanent magnetism in the ship.

(3) The cable connecting the transmitter unit to the detector housing must be waterproof and water stopped. Three conductors are required of AWG 24 or larger wire. Electrical shielding is not known to be required but is preferred. Very limited tests with unshielded cables were satisfactory. The VTS installation uses three shielded pairs with each pair connected in parallel. The shields are connected to the battery return at the transmitter unit and are not connected at the detector end. Maximum cable resistance that can be tolerated is 5,000 ohms. (AWG 24 wire has 25 ohms/1000 ft).

3. MAINTENANCE AND OPERATION

a. End of roll of paper in the printer is indicated by a pink stripe on the right side of paper near the end of the roll. If the paper is not replaced, the printer will cease to print. No harm will result to the system. Ship passings will then be indicated by the 20 second lights only.

b. If the receiver/display fails to operate at all - turn the volume up and the squelch off on receiver. Static and signals from interference should be present. The receiver is defective if nothing can be heard on the speaker.

c. Turn main power switch off. Wait a few moments and turn it back on. All indicator lights will come on briefly if decoder is operating properly.

d. Water in the detector housing will cause the transmitter to go into a rapid transmission rate and saturate the RF channel. The detector must be disconnected as soon as possible to remove interference from the RF channel and to prevent complete discharge of the battery pack. Slight leaks may cause the detector to signal every 10 seconds as will movement of housing on the side of the channel.

e. Occasionally, an erroneous digit will appear in the NA number printout. This is due to interference on the RF channel or to lowered battery voltage at the transmitter.

f. A major items parts list is provided.

MAJOR ITEM PARTS LIST

| <u>ITEM</u> | <u>MANUFACTURER</u> | <u>COST</u> |
|--------------------------------|---|-------------|
| Corner Relecting Antenna | Sinclair Radio Labs., Model 228 | \$ 268.00 |
| Receiver | Sonar Radio Corp., Model FR105 | 180.00 |
| Printer | Datel Systems Model DPP-7A5 | 475.00 |
| Clock | Datel Systems Time Clock, 6 digit panel mount, Digital Model DTC8300A6A2 | 299.00 |
| Enclosure | Treeko Sales, Beltsville, MD #171016-23-X | 98.15 |
| Batteries each | Mallory Battery Co., #317745T2 (25 cells req'd per pack) | (ea) 4.08 |
| Transmitter Housing | Mirax Chemical Co., Drum, Steel MS 27684. Inside height 40", no reinforcing rings | 24.50 |
| Waterproof Cable Connectors | Rochester Corp., Houston, Texas Cable: Plug, connector, cable type HDL-3 CCP | (ea) 14.80 |
| | Housing: Receptacle Bulkhead Type HDL-3 BCR | (ea) 14.80 |
| Waterproof Cable | Times Wire & Cable Co., #MI 31099 | 300.00/1kft |
| Magnetic Detector | Dorsett Electronics, Tulsa, OK GSQ 180(V) NSWC 1018 | 100.00 |

MAJOR ITEM PARTS LIST

| <u>ITEM</u> | <u>MANUFACTURER</u> | <u>COST</u> |
|---|--|-------------|
| Transmitter | T1233 Transmitter FSN 5820 - 421 - XXXX or - 451 - XXXX or - 784 - XXXX Last 4 digits specify channel No. Consult ECOM for digits corresponding to channel deisred | 150.00 |
| Encoder | KY678(GSQ)FSN 5820- 00-484-8651 | 30.00 |
| Connector for ID each Selection Circuit | TA 386 Bendix Corp., N.Y. (120 day delivery) | (ea) 33.00 |